Instruments

THE MAGAZINE of MEASUREMENT and CONTROL

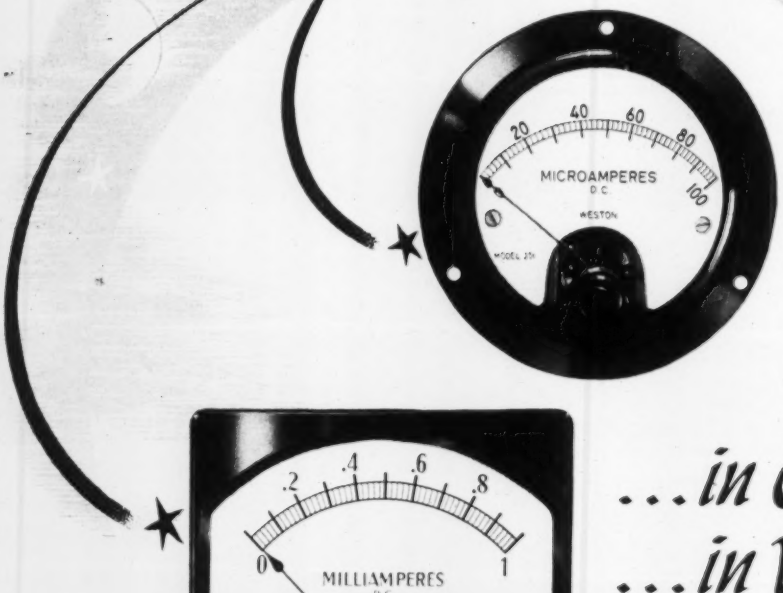
Vol. 23 JANUARY 1950 No. 1

INCLUDING THE *Journal of the Instrument Society of America*
AND THE *Journal of the Southern California Meter Association*

EAST ENGIN. LIBRARY

CONTROL BOARD AND REMOTE-MEASUREMENT STATIONS
new wind tunnel of Glen L. Martin College of Engineering and Aeronautical Sciences at the University of Maryland, College Park, Md.

Trustworthy



...in Constancy
...in Value

Wherever an electrical measurement provides essential information . . . whether in the manufacture of electrical components, the inspection of purchased parts or finished products, or in the operation of some electrical machine . . . far-sighted buyers specify "meters by WESTON". Experienced buyers know that in value, and in performance, there is no substitute for WESTON instruments. Ask your nearest WESTON representative for all the facts, or write for bulletin A-7-B. WESTON Electrical Instrument Corporation, 591 Frelinghuysen Avenue, Newark 5, New Jersey.

WESTON
Panel Instruments

Albany • Atlanta • Boston • Buffalo • Charlotte • Chicago • Cincinnati • Cleveland • Dallas • Denver • Detroit • Houston • Jacksonville • Knoxville
Little Rock • Los Angeles • Meriden • Minneapolis • Newark • New Orleans • New York • Orlando • Philadelphia • Phoenix • Pittsburgh • Rochester
San Francisco • Seattle • St. Louis • Syracuse • Tulsa • Washington, D. C. • In Canada, Northern Electric Company, Ltd., Powerlite Devices, Ltd.

Instruments The Magazine of
MEASUREMENT and CONTROL

Published Monthly by The Instruments Publishing Company
921 Ridge Ave., Pittsburgh 12, Penna.

INDEX TO VOLUME 23, 1950

Issue	Pages
January	1-100
February	101-208
March	209-308
April	309-416
May	417-524
June	525-632
July	633-732
August	733-864
September	865-964
October	965-1088
November	1089-1264
December	1265-1320

Subject Index

A

Abrasive Wheels, Refacer for 164
Abrasion Wear Tester 694
Acoustic Measurements Made Standards 1240
Air Conditioning, Automatic Controls for 286
Air Dehumidifiers 484
Air Filter and Regulator, Instrument 942
Air Pressures for Pneumatic Controllers and Transmission Systems 179
Air Valve for "Hold-position" Applications 706
Air Valve, Manual-operation 1280
Air-filter Washer 706
Air flow Meter, Temperature-compensated 366
Air-gaging Spindles 44
Air Pressure Booster, Improvised 337
Air-velocity Meter 806
Aircraft and Flight-control-system Analog 568
Aircraft, Instrumentation Requirements for Airline 136
Aircraft Navigating System, Automatic 690
Aircraft Navigation Radio Receiver 268
Aircraft Navigation Range Simulator 482
Airport Recorder, Multi-channel 262
Alarm, Low-level Boiler 1164
Ammeter, Accessories for Clamp-on 1276
Ammeter, Connectionless 48
Amplifier, Biological-research 378
Amplifier, Bridge 934
Amplifier, Chain-pulse 700
Amplifier, D-c, Breaker 698
Amplifier, Decade 813
Amplifier, Demonstration Magnetic 252
Amplifier, Direct-coupled 378
Amplifier, Dynamic Strain 690
Amplifier for Instruments, Power frequency 934
Amplifier, 40-240-Mc 166
Amplifier, Magnetic 43, 920
Amplifier, Pentagrid 946
Amplifier, Plug-in Line 1036
Amplifier, Servo 927
Amplifier, Wide-band D-c 584
Amplifiers, Stabilized D-c, Indicating 697
Amplifiers, Tuned Audio 593
Amplistat, Educational 52
Amplitude Modulator 378
Analog, Aircraft and Flight-control-system 568
Analog Component, Control-function 928
Analog for Oil Industry 454
Analysis of Sphygmomanometry, An 1134
Analyzer, Capacitor 700
Analyzer, CRO-type 688
Analyzer, Dynamic 1148
Analyzer, Halogen 684
Analyzer, Industrial Electrical 47
Analyzer for Low Temperature Distillation, Automatic 1028
Analyzer, Microwave Spectrum 1030
Analyzer, Oxygen 1028
Analyzer, Particle-size 1031
Analyzer, Polarographic-method 474
Analyzers, Continuous 1130
Application of Bourdon Tubes to Pressure Indicating Devices, The 1068
Application of Computing Mechanisms To Industrial Instruments 614
Application Factors Affecting the Regulation of pH in Industry, Some 38, 152
Application of the Fundamental Gas Laws to Orifice Metering 517
Atmosphere Sampler 484
Attenuator, Network 1284
Attenuator, Thermostat-controlled Logarithmic 487
Attenuators 388
Attenuators, Precision 488
Automatic Control Helps to Save the Cost of the Furnace by Increasing Production of Others 256
Automatic Control, A New Concept of 1218
Automatic Controls for Air Conditioning 286
Automatic Optical Contour Follower 345
Automatic X-Y Coordinate Millivolt Recorder 328
Automatize Quality Control? 335
Autopilot for Executive and Light Planes 1032
Autotransformer, TV test 382

B

Balance 1271
Balances, Laboratory 588
Ballistic Research In Rocketry, Instrumentation for Exterior 184
Ball Bearings, Tool for 710
Barometer, Aneroid 920
Barrel Filler, Automatic 588
Barrel, Schmidt Optical 1032
Batteries, Miniature 274
Battery, Mercury 706
Battery, Silver-type Storage 946
Battery, Small-size Silver-type 270
Battery-cell Tester 378
Beakers, Stainless steel 704
Bearing Temperature Control System 922
Bellows, Stainless Steel 1284
Bellows-actuated Flow Meters, History of 79
Bellows-type Flow Meters, Rupture-proof 1300
Bent Gun for CRO's 1028
Betatron at Chicago University, 100-Mev 1174
Blow Torch, Alcohol 710
Boosters, Fluid-pressure 602
Bore Gage, Dial 262
Bottle, Reusable-Reagent 1283
Bourdon Tubes to Pressure Indicating Devices, The Application of 1068
Box, Multiple Outlet 1168
Brake-lining Tester, New 466
Bridge, Bolometer 1158
Bridge, Capacitance 933
Bridge, Impedance 933
Bridge, Line-operated Resistor-testing 166
Bridge, Resistance-capacitance Comparator 1275
Bridge for Thermometry, Portable 686
Bridge, VHF 378
Bridge, Wheatstone-megohm 697
British Electronics Symposium and Exhibition, The 1950 1132
Burette-and-valve Assembly 694
Burner, Bunsen 1166

C

Cable-fault Locator 489
Calculation of Orifice Meter Charts by the Square-root Planimeter Method 1081
Calculation of Orifice Meter Coefficients for Natural Gas 1311
Calculator for Differential Linear Expansions 45
Calculator, Isotope 940
Calibrating Standard for Pressure Instruments 1148
Calibrating Watthour Meters, New Device for 1018
Calibration of Gas Flowmeters 908
Calibrator, Frequency 599
Calibrator, Signal 167
Caliper, Vernier 591
Caltech's "Weather Factory" Depends on Instrumentation 1018
Camera, Celestial Surveying 254
Camera, Data-recording 816
Camera, Flat-plate X-ray Diffraction 1154
Camera, Oscilloscope 595
Camera, Recording 255
Camera, Synchronous 162
Cameras, Photomicrograph 1153
Capacitors, A-c, Electrolytic 57
Capacitors, Bakelite-cased 711
Capacitors, Electrolytic 55
Capacitors, HV R-f 857
Capacitors, Metallized-paper 836
Capacitors, Miniature 710
Capacitors, Radio-noise-suppressor 1054
Capacitors, Tubular 711
Capacitors, Zero Temperature-coefficient 837
Carbon Determination Apparatus 1156
Carbon Monoxide Recorder 364
Catalytic Cracking Process, Development of Wide Range Radiation Type Level Control for the Houdriflow 1074
Cathetometer, Coordinate 808
Cathetometer, Shop 260
Cathode-ray Tube, Five-gun 45
Celestial Surveying Camera 254
Centrifuge, High-speed 809
Chart Drive, Pneumatic 694
Chart Reading by the Emco McGlauchy Integrator Method 1082
Chemical Feeder-blender 257
Chemical Process for Instrumentation, Design of a 140
Chemical-problems Circular Slide Rule 264
Chilling Unit, Sub-zero 1279
Chokes, Special Coils and 710
Chopper, D-c-a-c, 378
Chopper, Wide-range D-c A-c, 491
Choppers, D-c-drive 56
Choppers, D-p, D-c, 1040
Chromium Determination, New Method for 574
Cinemicrographic Focusing Unit 1280
Circular Slide Rule for Radioactivity 498
Clamp, Laboratory Frame 828
Clamp for Power Leads, Safety 835
Classifier, Micro-particle Size 696
Cleaner, Instrument 494
Cleaner, Optical Lens 810
Clip, Test 588
Clutch, Adjustable Speed-control 462
Clutch, Controlled Magnetic-fluid 456
Coatings-thickness Gage 156
Coil Checker 375
Coils and Chokes, Special 710
Coil-winding Counter, Quarter-turn 159
Color Comparator, Extreme-sensitivity 250
Colorimeter, Automatic 366
Colorimeter for Cotton, Automatic 1034
Colorimeter, Illuminator and Viewer for 366
Colorimeter, Nepho 477
Colorimeter, Photoelectric 929
Combustion Air Control System for Single-cylinder Testing 904
Combustion Apparatus 46
Combustion Furnace 42
Combustion Safeguard for Gas Burners 830
Combustion Tubes 948
Comparator, Coordinate 1032
Comparator, Linear 1032
Comparator, Surface Finish 1046
Comparator for Testing Abrasive Products, Sonic 926
Comparator, Thread 828
Components, Electromechanical Resolving 157
Components, TV 270
Computer, Ten-equation Electrical 252
Computing Mechanisms To Industrial Instruments, Application Of 614
Computing System for Retail Stores, Automatic 582
Concept of Automatic Control, A New 1248
Concepts of Instrumentation as Taught at The University of Tennessee 34
Concepts of Modern Gaging As Applying To Pneumatic Gages 616
Conductivity Cells 838, 946
Conductivity Cells, Laboratory 946
Conductivity Measurement, Solution 664
Connector, Miniature 392
Connectors, Glass-sealed 828
Connectors, High-voltage 395
Connectors, Miniature 1281
Contact-making Electrical Indicating Instruments 1153
Container for Liquid Hydrogen 45
Containers, Pressure-sample 262
Contour Follower, Automatic Optical 345
Control, Cooling-water 474
Control Installation Pays For Itself in One Week 342
Control Point Location Upon Column Control, The Effect Of 719
Control, Pump Protecting 483
Control, Side Register 1151
Control System, "Fail-safe" Electronic 564
Control Transformers 55
Control Valve, Non-lubricated Cylindrical 165
Control Valves, Notes on 784
Control Valves and Regulators, High-pressure Design and Application of 621
Control Valves, Users' Requirements for 806
Controller, Automatic Flow-rate 1028
Controller, Automatic Temperature 1030
Controller, Batch Integrator 916
Controller, Dragless-pointer Automatic 156
Controller, Liquid-level 368, 832
Controller, Pneumatic Current 595
Controller, Potentiometer 800
Controller for Proportioning Pumps, Automatic 46
Controller, Pump-sequence 1152
Controller, Pyrometer 364
Controller, Solution Conductivity 809
Controller, Yarn-tension 588
Controllers, Air-operated 685
Controllers, Rate-mode Electric-type Automatic 1148
Controllers, Time Cycle 251
Controlling Costs in the Production and Distribution of Utility Fluids 341
Controls, Cut-off Register 482
Converter, Proportional-counter 274
Cooling Unit, Compressed-air 706
Count Detectors, High-resolution 167
Counter, Alpha-beta-gamma 927
Counter, Alpha-Beta-Gamma Portable 822
Counter, Alpha-particle 168, 171
Counter, Bismuth-wall Gamma 824
Counter Converter, Proportional 274
Counter, Electric 481, 812
Counter, Electronic 487
Counter, High-speed Industrial 692
Counter, High-speed Revolution 1044
Counter, Mica-window 168
Counter, Neutron 824
Counter, Predetermined Electronic 156
Counter with Prefinish Chamfer, Radiation 1164
Counter, Prospectors' Geiger 586
Counter, Quarter-turn Coil-winding 159
Counter, Recording 479
Counter, Stroke 262
Counter, Stroke-type Printing 157
Counter Tube, Radioactivity 824
Counters, Alpha and Beta 170
Counters, Cosmic-ray 168
Counters, Instrument-application 1269
Counters, Radioactivity Proportional 586
Counting Rate Meter 938
Counting Unit, "Plug-in" Photoelectric 1044
Counting Units, High-speed Decimal 1300
Count-rate Indicator, Radioactivity 169
Counting-rate Meter for Radioactivity Measurements 1276
Coupler, High-voltage 711
Crane Scales, Hydraulic 42
Cut-out, Temperature-limit 176
Cutting the Cost of Control 708

D

Data-storage Systems, Magnetic 252
D-c, Integrator-motor 493
D-c, Microvoltmeter 1161
D-c, Power Supplies, Regulated 385
D-c, Power Supply 268, 702, 820
D-c, Power Supply, Regulated 384, 820
D-c, Supplies, High-voltage 701
D-c, Supply, Regulated 384
Decade Inductors 474
Decade Scaler 1163
Dehumidifiers, Air 484
Delay Lines, Custom-built 834
Demagnetizer 935
Densitometer, Photometric 1154
Densitometers and S. G. Controllers, Industrial-liquids 252
Design of a Chemical Process for Instrumentation 140
Design Considerations in Connection With the Use of High Speed Thermometry for Telemetering, Some 1298
Detector, Fluorescence 1043
Detector, VHF 386
Diagnosing Instruments, Automatic Medical 940
Dial, Adjusting Knob with Turn-counting 602
Dial Indicators for Transmission Systems 159
Dial for Time-delay Relays, Adjustable 830
Diamond-Indentation Hardness Testing Method Saves Time and Cuts Costs 243
Diamond-scratch Tester, Shear-hardness and 596
Diaphragm-motor Pinch-type Flexible-wall Valve 165
Diaphragm-pinch Valves 53
Diffraction-grating Production, Advances in 841
Diffusion Pump, High-vacuum 270, 272
Digital Remote-recording System 158
Diode Modulator 700
Direction Finder for Aircraft, Automatic 586
Discontinuer, High-voltage 1169
"Down Time" (and Resultant Costs) Cut Down 346
Drafting Instruments, Glare-free 828
Drilling Tool, Universal 482
Drives, Spring-powered 830
Dual Automatic Motor Speed Control and Speed Proportioning System 468
Dust Collector, Filterless 50
Dynamic Accuracy in Temperature Measurement 66
Dynamometer, Fractional-hp 1047
Dynamometer, A Mainspring 251
Dynamometer for Measuring Forces on a Drill, A 560
Dynamometer, Shaft-hp 158
Dynamometers and Indicators, Strain-gage 445
Dynamometers, Traction-type 262
Dynamometers, Adjustable Linkage for 588

E

Economies of Instrumentation 28, 1125
Educational Amplistat 52
Electric Motors for Instrumentation Purposes, Special 1049
Electric Power Re-enters Servo Race 551
Electrical Analyzer, Industrial 47
Electrical Indicating Instruments 267, 814, 1034, 1158, 1274
Electrical Indicating Instruments with Interchangeable Face-plates 48
Electrical Indicating Instruments, Miniature 1273
Electrical Instruments, "Light-spot pointer" Type 596
Electrical Instruments, Notes on the Care and Use of 1256
Electrical Instruments, Portable 598
Electrical Pickoffs for Instrumentation of Pilotless Aircraft 347
Electrical Resolvers 595
Electrical Tester, Multi-purpose 165, 486, 491, 598, 698, 813, 1036
Electrical Units, Establishment and Maintenance of the 469
Electrodes, Moisture-proof Glass 386
Electromechanical Resolving Components 157
Electrometer Pentode, Subminiature 710
Electrometer for Radioactivity 587
Electron Microscope 580
Electron Tubes, Industrial 172
Electron Tube Testers 485
Electron-tube Development, Rugged 464
Electronic Circuit, Shooting an 450
Electronic Counter 487
Electronic Filter, Variable 162, 816
Electronic Inverter 597
Electronic Rectifier Units 1034
Electrostatic Generators 380
Electrostatic Kilovoltmeter 485
Electrostatic Phasing Equipment 484
Endurance Test Instrumentation, Truck-Motor 456
Engineering and Invention, The Relationship Between 258
Engraving Machines 691
Etching Equipment, Tracer guided 1046
Expansions, Calculator for Differential Linear 45
Extensive Meter 51, 157, 808
Extensometer, A High-temperature 448

F

"Fail-safe" Electronic Control System 564
Fatigue-testing Machine 162
Feeder, Chlorine 159
Feeder, Dual syringe 157
Feeder-Blender, Chemical 257
Fermentor, Laboratory 834
Filling Machine, Electron-tube controlled 264
Film-adhesion Tester 162

Filter, Narrow-bandwidth Green 261
Filter, Ultra-low-frequency Band-pass 1052
Filter, Ultra-low Frequency Rejection 1054
Filter, Ultrasonic Half-octave 810
Filter, Variable Electronic 166, 816
Filters and Reactors, Audio Wave 390
Fire-alarm Box, Combination Operation 1051
Fittings, Instrument-tubing 1051
Five-gun Cathode-ray Tube 45
Fixed-Bed Catalytic Processes, Measurement and Control Problems in Typical 132
Flame Detector 157
Flame-failure Alarm 371
Flame-failure Safeguard 829
Flask and Separatory Funnel, Combination 829
Flaw Locator For Transparent Parts 342
Flight Data, New Method of Recording 36
Flow Integrator-controller 474
Flow Meters, History of Bellows-actuated 79
Flow Regulators, Adjustable 1047
Flow Tester, Cement 695
Flow-Control Processes, The Effect of Transmission Distance on the Stability of 1191
Flow-operated Switch 496
Flow-rate Indicator 256
Flow-rate Indicators 368, 580
Flow-rate Recorder, Mercuryless 157
Flowmeter, Caustic Soda 1156
Flowmeter-calibration Unit 802
Flowmeters, Variable-area 582
Fluid Proportioning Cuts Cost 338
Fluorimeter, Multi-range 1270
Fluorinating Cell 480
Force Reactions in Control Valve Plugs and their Influence on Diaphragm-motor Design and Operation, Unbalanced 1252
Four-channel Oscilloscope 45
Fractionating Column, Feed Section for 272
Frequency Generator 816
Frequency Generator, Constant- 166
Frequency Meter 697
Frequency Response of Instruments 506
Frequency Response Recorder 920
Frequency Standard 860, 1159
Fundamental Gas Laws to Orifice Metering, Application of the 517
Fundamentals of Orifice Meter Measurement 518
Furnace, Electric 1272
Furnace, Laboratory 42

G

Gage Blocks, Accessories for 387
Gage, Bore 480
Gage Converter, Snap- 370
Gage, Dial Bore 263
Gage, Film-thickness 587
Gage, Flow 692
Gage Glass 1280
Gage, Internal Groove 827
Gage, Snap 45, 481
Gage, Ultra-high-vacuum 800
Gages, Spline 391
Gaging Plug, Contact 1277
Gaging Spindles, Adjustable 1055
Gamma Survey Indicator 170
Gamma-ray Detector 602, 824
Gamma-survey Detector 171
Gas Balance, Laboratory 692
Gas Burners, Improvement of Laboratory 459
Gas Torch 710
Gas-flow Control Apparatus 696
Gearbox 1169
Gearmotor 1048
Geiger Counter Kit 822
Geiger Counter, Prospector's 1163
Geiger Tube 939
Generator, Constant-frequency 166
Generator, Double-pulse 932
Generator for Electron Tubes, Curve 1016
Generator for Magnetic Tape, Control-track 810
Generator, Marker 1034
Generator, Pneumatic Totalizer and Control-action 1150
Generator, Pulse 932
Generator, Signal 1162
Generator, Square-wave 375
Generator, Standard-signal 698
Generator, Sweep 931
Generator, Sweep and Marker 1034
Generator, Sweep-signal 491
Generator, Tachometer 808
Generator, Two-signal Audio 1160
Generator, Ultrasonic 1280
Generators, Electrostatic 380
Generators, Random-noise 933
Getting Your Money's Worth 504
Gish-Rooney-type Resistivity Apparatus 487
Glass Orifice Plates 364
Glassmeter, Portable 85-degree 1032
Graphic Instrumentation—A new Tool for Industry 1188
Grid for Cathode-ray Tube, Transparent Reference 1005
Ground Testers, Earth-resistivity-type 49

H

Hardness Tester, Core 807
Hardness Tester, Portable 164, 924
Hardness Tester, Scratch 159, 164
Hazardous Locations, Multiple-signal System for 256
Hazemeter for Plastics, etc. 927
Heat-flow Meter 688
Helium Crystal 1271
High-pressure Design and Application of Control Valves and Regulators 521
History of Bellows-actuated Flow Meters 79
Holder for Indicators, etc., Magnet-base 393
Holder, Thermocouple 684
Hot Plate, Electric 269
Hot Plate, Thermostatic 498
Hot-plate, Laboratory 43
Humidity Recorder-controller 472
Humidity Rule, Pocket Psychrometer and 582
Humidity-indicating Printed Cards 586
Humidity-temperature Indicator 478
Humidity-temperature Test Apparatus with Program Control 262
Hurricane Tracking, Industrial Radar for 73
Hydraulic Power Unit, Light-weight Rotary 940
Hydraulic Valve, Two-pressure 54
Hydraulic-line Filter 493
Hydrometer, Unbreakable 266
Hygrothermograph Cut Costs, Slight Alterations of a Standard 241

I

Ignition-harness Tester 376
Illumination Meter 684
Illumination Recorder 41
Illuminator, Pocket-microscope 40
Illuminator and Viewer for Colorimeter 366
Illuminometer for Street Lights 807
Impact Tool for Bolts, Screws, etc. 1167
Improvised Air-Pressure Booster 337
Indicator, Boiler Scale Thickness 1267
Indicator, Bridge Balance 1040
Indicator, Color-temperature 922
Indicator, Combustible-gas 1271
Indicator, Humidity-temperature 478
Indicator, Laboratory Millivolt 591
Indicator for LVDT Pickups, Self-powered 488
Indicator, Moisture-content 692
Indicator, Phase Sequence 592
Indicator, Polyphase Sequence 1276
Indicator, Pulse Rise-time 492
Indicator for Solder, Tin-content 588
Indicators, Dew-point 690
Indicators, Flow-rate 368
Indicators, Force 866
Indicators, Strain-gage Dynamometers and 445
Inductance Method for Remote Indication of Tank Level, A New 562
Industrial Television System 474
Infrared Gas Analyzers, Instrumentation and Auxiliary Equipment for Automatic 552
Infrared Spectrometer 686
Infrared Spectrophotometer 364
Input Control Unit for Temperature-control Systems 41
Inspection and Gaging Facilities in the U.S.A. 186
Inspection Lamp 44
Inspection Magnifier 45
Inspection Microscope and Illuminators, Surface Plate with 44
Inspection, By Optical Projection 404
Inspection Polariscope for Dry and Immersed Parts 340
Inspection, The Relationship Between Engineering and 358
Inspector for Eccentric Shafts, Automatic 1045
Institute of Radio Engineers, 1950 National Convention, The 129
Instrument Line, Interchangeable-component 684
Instrument Mechanic Training 281
Instrument Oiler 44
Instrument Panels, Enclosed 272
Instrument Repairman Trade Apprentice Training Program 280
Instrument Shop Layouts 401
Instrumentation and Auxiliary Equipment for Automatic Infrared Gas Analyzers 552
Instrumentation Course at Bucknell 346
Instrumentation Course at L. A. H. J. C. 346
Instrumentation Course at Pratt Institute, The 670
Instrumentation for Exterior Ballistic Research In Rocketry 184
Instrumentation Problems of the Vibration Field Test Engineer 142
Instrumentation, Purdue's Course in Engineering 31
Instrumentation Requirements for Airline Aircraft 136
Instrumentation in Rubber Processing 723
Instrumentation as Taught at The University of Tennessee, Concepts of 34
Instruments Cut Costs, Compared with Manual Methods 339
Instruments in the Oil Laboratory, Some 1240
Instru-merriment 249
Insulation Tester 269, 592, 699
Insulation Tester, Production-line 208
Integrator-motor, D-c 493
Interferometer, Michelson 922
Interlock Receptacle with Breaker 1056
Interlock, Safety High-voltage 496
Intermodulation Meter 1162
Intermodulation Set 937
Ion, Resonance Type Mass Spectrometer Tube 1028
Ion-exchange-bed Indicator 367
Isolator, Shock and Vibration 1283
Isotope Calculator 940
Isotopes, Safe Handling of Radioactive 467

J

Jack, Telephone-type 944
Jet Instrument Trainer, USAF's New 678
Journal of the Instrument Society of America 65, 181, 227, 295, 503, 697, 713, 845, 951, 1061, 1177, 1295
Journal of the Southern California Meter Association 79, 189, 285, 409, 517, 621, 723, 853, 957, 1081, 1197, 1311

K

Kilovoltmeter, Electrostatic 485

L

Laboratory Balances 588
Laboratory Furnace 42
Laboratory Gas Balance 692
Laboratory Hot-plate 43
Laboratory Pump 829
Laboratory Water Baths 42, 43
Lamp, Magnetic Base 946
Lead Shield 824
Lens, Electron Microscope 942
Lens, High-speed Wide-angle 944
Lens and Light-source, Inspection 831
Level Control for the Houdriflow Catalytic Cracking Process, Development of Wide Range Radiation Type 1074
Level Indicators 366
Level, Magnetized Machinists' 1046
Light Source, High-intensity 160
Light Source, Schlieren 807
Light-concentrator for Instrument Shops 948
Liquid Batching System 916
Liquid Counter Set 830
Liquid Fraction Dispenser and Collector 306
Liquid Hydrogen, Container for 45
Liquid Meter, Predetermined-quantity 686
Liquid-level Controller 368, 832
Liquid-level Controller, Displacement-type 41
Liquid-level Gaging for Aircraft, A New Compensated-float Method of 1006
Liquid-level Transmitters 684
Loading Quartz Crystals to Improve Performance 1020
Locator, Radio Interference 700
Logarithmic Attenuator, Thermostat-Controlled 487
Long Range Multi Channel Telemetering System 70
Lubrication Signal for Automotive Vehicles 256
Lugs, Wiring Terminal 269

M

Machinability Tester 162
Machine, Gaging and Segregating 1279
Machine-control Centers 162
Magnetic Amplifier 43
Magnetic Amplifier, Demonstration 252
Magnetic Data-storage Systems 252
Magnetic Micrometer 44
Magnetic Starters 597
Magnetic Tape Recorder 264
Magnetic Tape Recording in Telemetering, Uses of 1186
Magnetic-fluid Clutch, Improved 456
Magnetometer, Survey-type 467
Magnetometer, Universal 382
Magnetron 1168
Magnets, Permanent 694
Magnifier, Inspection 45
Magnifier, Pocket 393
Magnifier, Triplet 1031
Magnifying Glass, Machinists' 1278
Mainspring Dynamometer, A 351
Maintenance of Mercury-type Orifice Meters 1197
Maintenance of Pressure Gages 853
Manometer, Protected-glass 929
Manometers, Recording Flowmeter 584
Manometers, Reservoir-type 159
Manostat 41
Marker, CRO 1038
Marker for CRO's, Time 375
Mass Spectrometer, The 242
Matcher, Automatic Bearing Ball-and-race 482
McGaughy Integrator Method, Chart Reading by the Emco 1082
Measurement and Control Problems in Typical Fixed-Bed Catalytic Processes 132
Measurements Laboratory, GE's New 1140
Measuring Pressure Electrically, A New Method of 907
Mechanization of Plants Far Off, Complete 680
Mecohmmeter 46, 380, 698
Melting Furnace, Bench-type 704
Memory Units for NRS Computer 680
Mercury-filled System, High-temperature 160
Metal Sorter 687, 921
Metallograph 1156
Meter Kit for Flow-rate Studies, Triple 688
Metering Pump 272, 472, 684, 690
Metering Pump, Variable Discharge 1288
Method of Locating Defects in Oilfield Pipes, etc., Rapid 458
Method of Measuring Pressure Electrically, A New 903
Micarta Orifice Plates 346
Micro Switch 492
Micro Switches 495
Microbarometer 684
Micromanometer 687
Micromanometer with Electrical Pick-up, Diaphragm-type 1136
Micrometer, Dial 44
Micrometer, Magnetic 44
Microphotometer, Light-scattering 805
Microscope, Binocular 1155
Microscope, Combination Monocular and Binocular 1032
Microscope Illuminator, Pocket- 40
Microscope, Ore 807
Microscope, Pocket 252
Microscope, Shop 704, 828
Microscope, Stereoscopic 582
Microscope, Toolmaker's 265
Microscopes, Phase 921
Microscopes, Polarizing 482
Microtome, Ultra- 41
Millivoltmeter 814
Millivoltmeter, H-F 814
Millivoltmeter, High-impedance D-c
Mirrors, Front-surface 948
Mixer Crystal Test Set 1036
Mixer, Laboratory and Small-prod
368
Mixer, Utility 1165
Modified Gage Eliminates Maint
Costs 238
Modulation Monitor, FM 385
Modulator, Amplitude 378
Moisture Eliminator, Air-line 706
Moisture Meter 685
Moisture Tester 478, 1271
Moisture Tester, Cottonseed 1272
Moisture Tester, Hops 1272
Moisture Tester for Lumber 43
Monitor Kinescope, Seven-inch 1273
Monitor, Radiation 822
Monitor, Radioactivity 822
Monochromator and Spectrometer,
580
"More Power to America" Exhibit
Features Instruments 572
Motor, Fractional-hp 711
Motor Servomechanism, Low-speed 1249
Motor, Solenoid Starters 43
Motor Starter 43, 162
Motor, Timing 50, 600
Motor-control System, Educational 490
Motor-speed Control System 307
Mounting for Beta-ray Thickness
Traverse 1045
Multiple Pressure-transfer Device 350
Multiple-signal System for Hazardous
256
Multi-purpose Electrical Tester 165,
491, 598, 699, 813, 1036
Multi-range Electrical Tester 266

N

Narrow-bandwidth Green Filter 261
National Bureau of Standards Basic
Extensively Amended 1022
Navigation Instruments Respond
Human Mind 466
Neutron Intensity, A Permanent
of 249
New Method of Recording Flight Data
Noise and Distortion Measuring Set

O

Ohm Laid, Eight 929
Ohmmeter Kit, VTVM- 490
Oil-film Measured, Invisible 574
Oiler, Instrument 44
Oilfield Pipes, etc., Rapid Method
Locating Defects 458
Oils, Instrument 946
On-off Controller with "Anticipating"
tion 684
One-man Push-button Operation of
Stations "Only A Dream" 840
Optical Comparator, Pocket 250
Optical Projection, Inspection By 404
Ore Detector, Radioactivity-type 168
Orifice Edge Gage 1042
Orifice Meter Charts 957
Orifice Meter Charts by the Square-
Planimeter Method, Calculation of
Orifice Meter Coefficients for Natural
Calculation of 1310
Orifice Meter Measurement, Fundamentals
of 518
Orifice Meter Tests, AGA-ASME
on the Methods Used in the 1949
Orifice Metering, Application of
Fundamental Gas Laws to 517
Orifice Meters, Maintenance of Mercury-
type 1197
Orifice Meters, Stuffing Box for High-
pressure 802
Orifice Plates, Glass 364
Orifice Plates, Micarta 346
Oscillator, Audio 1275
Oscillator, Ultra-low-frequency 485
Oscillogram, Reader-analyzer for 472
Oscillograph 1040
Oscillograph, CRT 1036
Oscillograph, Direct-inking 266
Oscillograph Galvanometers 366, 1040
Oscillograph, Impulse-test C-r 818
Oscillograph, Square-coordinate Pen-type
1149
Oscillograph Tube, Seven-inch 1274
Oscillographs, Magnetic 814
Oscilloscope 376
Oscilloscope Carriage 46
Oscilloscope, Cathode-ray 45, 818
Oscilloscope, C-r 1038
Oscilloscope, Eight-channel Seismograph
1158
Oscilloscope, Five-inch 818, 1038
Oscilloscope, Five-inch C-r 817
Oscilloscope, Four-channel 45
Oscilloscope, Portable 380
Oscilloscope, Service-type 820
Oscilloscope, Seven-inch 1038
Oscilloscopes, Cathode-ray 45
Oscilloscopes, Cathode-ray 598, 936
Oven, Electric Drying 1165
Oven, Laboratory 271
Oven-temperature Tester 44
Oxygen-purifying Train 830
Ozonator, Aging-test 924

P

Panel Engraving Instrument 703
Panels, Enclosed Instrument 272
Panels, Graphic 1128
Panels, Illuminated 692
Paper Industry, Some Considerations in the Application of Instruments to the Pulp and 144
Paper Tensiometer 372
Parking Meter 804
Pen for Recorders, Ball-point 424
Pen, Recording Chart 384
Permeameter, Portable 158
pH in Industry, Some Application Factors Affecting the Regulation of 38, 152

Tester, Brake-lining 466
Tester, Circuit 48
Tube, Fitting, Flareless 392
Tube Flaring Tool 1056
X-ray Tube, "World's Smallest" 270
X-Y Coordinate Millivolt Recorder, Au-
C

pH Meter, Line-operated 474
Phase Changer 700
Phase Monitor, R-f. 49
Phasemeter, Precision 1160
Phosphorescent Screen 293
Photocell for Color Film 695
Photocell, Hermetically-sealed 271
Photocopying Unit 809
Photoelastic Stress Analysis, Three-dimensional 570
Photoelectric Control, Delayed Action 1278
Photoelectric Counting Equipment 928
Photoelectric Light Recorder 472
Photoelectric Pickup 273
Photoelectric Units, Subminiature 805
Photomicrographic Apparatus 690
"Photomicrometer" for Measuring X-Ray Diffraction Patterns, A 460
Phototube, Multiplier 56, 57, 391, 1168
Pickup, Photoelectric 273
Pickups, Self-powered Indicator for LVDT 488
Pilot Light 709
Pilotless Aircraft, Electrical Pickoffs for Instrumentation of 347
Pipe-line Shock Absorber 271
Pipettes, Semi-automatic 260
Plotting Table 703
Plug-and-Lamp 835
Pneumatic Bridge Speeds Precision Measurements 344
Pneumatic Gages, Concepts Of Modern Gaging As Applying To 616
Pneumatic Hand Tool 839
Pneumatic Power Unit, Double-acting 686
Pneumatic Power Unit, Piston-type 805
Pneumatic Power Units, Tunable 800
Pneumatic Relay, Snap-action 252
Pneumatic Weighing In Process Control Systems 1303
Polarimeter 808
Polariscope, Dynamic Stress 1150
Polarizing Microscopes 482
Polarographic-method Analyzer 474
Polariscope for Dry and Immersed Parts, Inspection 340
Positioning Device, Electrically-operated 1266
Positive-displacement Liquid Meter, The Two-rotor Type of 409
Potential Divider 494, 710
Potential-gradient Meter May Have Effect on Corona and Radio Influence 572
Potentiometer, Portable 477
Potentiometer for TC Measurements, Deflection 934
Pourer for Acids, Safety 704
Power Supplies, Adjustable 489
Power Supply 382
Power Supply for Breakdown Testing 47
Power Supply, D-c, 268, 820
Power Supply, Duplex Regulated 931
Power Supply, Fifty-kv. 820
Power Supply, Miniature High-voltage 489
Power Supply, Regulated 485, 820
Power Supply, Regulated D-c, 166, 384, 820
Power Supply, R-f, 384
Power Supply, Shaker 1270
Power Supply, Voltage-regulated 1042, 1275
Power Unit, Linear 820
Power Units, Hydraulic 472
Pre-amplifier, Wide-band 374
Predetermined Electronic Counter 156
Pressure Analysis Systems, Engine 802
Pressure Bombs, Reid Vapor 587
Pressure gage, Illuminated 41
Pressure Gage, Square Flush-case 1152
Pressure Gages, Maintenance of 853
Pressure Instruments, Temperature and 580
Pressure Pickup, Dynamically-balanced 1030
Pressure Pickup for Telemetering 160
Pressure Snubbers 164
Pressure Switch 498
Pressure Switch, Differential 1164
Pressure Switches, Explosion-resistant 1044
Pressure Telemetering System 474
Pressure and Temperature Recorders 472
Pressure Transmitter 156, 479
Pressure-analysis System, Dynamic 802
Pressure-block Gages 371
Pressure-Measuring System, Dynamic 920
Pressure-sample Containers 267
Pressure-transfer Device, Multiple 350
Probe, Alpha Scintillation 938
Probe for D-c, VTVM, Infinite-impedance 593
Probes, High-voltage 382, 946
Process Control Principles To Chemical Engineers, The Teaching of 557
Process Control Systems, Pneumatic Weighing in 1303
Process Monitoring Systems 1070
Production and Distribution of Utility Fluids, Controlling Costs in the 341
Program Recorder-Controller 685
Programming Control for Burners 42
Projector, Colorslide 376
Projector, Filmstrip 1155
Projector, Stereoscope-effect 692
Projector, Universal 593
Projector, Vertical Image 807
Proportional-counter Converter 274
Proportioning Pumps, Automatic Controller for 40
Proposed Tentative Standard 179
Protect American Instruments Against Tariff Cuts 895
Psychrometer and Humidity Rule, Pocket 582
Pulp and Paper Industry, Some Considerations in the Application of Instruments to the 144
Pulse Generator 932
Pulse Generator, Double 932
Pulse Generator, General-purpose 374
Pulse Rise-time Indicator 492
Pump, Filter 1107
Pump, Metering 272, 472, 684, 690
Pump, Miniature Controlled-volume 1266
Pump, Variable Discharge Metering 1268
Purdue's Course in Engineering Instrumentation 31
Pyrometer, Indicating 584

Q

Quality Control, Automatize 335
Quality Control Indicator Cuts Production costs 336

R

Radar for Hurricane Tracking, Industrial 42
Radar-like Instruments Detect Speed Violators 454
Radial Internal Clearance Inspector 808
Radiation Pyrometer Receiver, Miniature 472
Radiation Pyrometry, Hermetically-sealed Receiver for 250
Radio-telemetering Receiver 55
Radioactive Isotopes, Safe Handling of 407
Radioactive Sample Carrier 385
Radioactive Tracers Used to Study Plating Process 454
Radioactivity, Circular Slide Rule for 498
Radioactivity Count-rate Indicator 169
Radioactivity Counter, Low-background Windowless 1165
Radioactivity Counters, Reset-type Register for 168
Radioactivity Demonstrator 275
Radioactivity, Electrometer for 387
Radioactivity Indicator 171, 385, 1042
Radioactivity Monitor for Workers' Hands and Feet 172
Radioactivity Proportional Counters 386
Radioactivity Shield 385
Radioactivity Shielding 387
Radioactivity Survey Meter 168
Radioactivity-hazard Survey Meter 168
Radioactivity-type Ore Detector 168
Radiography Technique Speeds Ship Salting 576
Rain Gage 52
Rain-makers Get Loan of Weather Instruments 1174
Range Simulator, Aircraft Navigation 482
Reactors, Audio Wave Filters and 390
Reactors and Transformers, Special-application 390
Reader-analyzer for Oscillogram 472
Receiver, Miniature Radiation Pyrometer 472
Receiver for Radiation Pyrometry, Hermetically-sealed 250
Recorder, Contour 588
Recorder, Direct-writing D-c, 916
Recorder, Magnetic Tape 264
Recorder, Miniature 580
Recorder, Multi-channel Airport 262
Recorder, Photoelectric Light 472
Recorder, Small Convertible 809
Recorder, Strain 688, 1148
Recorder-controller, Humidity 472
Recorder-controller, Strip-chart 260
Recorders, Ball-point Pen for 474
Recorders, Pressure and Temperature 472
Recorders, Rapid-pen-speed Millivolt 580
Recording Camera 255
Recording Counter 479
Recording Potentiometers and Bridges, Self-balancing 1148
Recording and Reproducing Instruments, Variable-area 160
Recording Systems, High-speed Photographic 916
Rectifier Cartridge 837
Rectifier, Low-current, Selenium 711
Rectifiers, Copper-oxide 55, 709, 835
Refacer for Abraser Wheels 164
Refractive-index Recorder 57
Refractometer 1155
Refractometer, Recording 396
Refractometer, Recording Microwave 1016
Refrigeration Temperature and Pressure Control 238
Regulator, Fluid-flow 1269
Regulator, Line-voltage 1165
Regulator, Register 1042
Relief Valve Pressure Bombs 587
Relationship Between Engineering and Inspection, The 358
Relay Assembly 602
Relays, Combination Sensitive and Power 1053
Relay Control, Simple Chatter-proof 1095
Relay, Electropneumatic Timing 173
Relay Enclosure 387
Relay, High-differential A-c, 1053
Relay, High-speed D-c, 387
Relays, Latch-type 826
Relays, Mercury 944, 1282
Relay, Miniature 57
Relay, Miniature Sensitive 1281
Relay, Motor-starting 390
Relay, Photoelectric 1169
Relays and Power Relay, Combination Prime 691
Relay, Sealed 944
Relay, Sensitive 498, 602
Relay, Snap-action Pneumatic 252
Relay and Microswitch Units 804
Relays 56
Relays, Antivibration 1053
Relays, Frequency-sensitive 389
Relays, Hermetically-sealed 601, 1167
Relays, High-speed 403
Relays, Light Sources for Photoelectric 602
Relays, Mercury 836
Relays, Pneumatic Time-delay 684
Relays, Polarized 392
Relays, Timer 600
Remote Control of 22 Cameras in Two Airplanes 456
Remote Indication of Tank Level, A New Inductance Method for 562
Remote-positioning System, High-Speed 564
Remote-recording System, Digital 158
Report on the Methods Used in the 1949 AGA-ASME Orifice Meter Tests 183
Report on Western Europe 637, 778, 906
Reset-type Register for Radioactivity Counters 168
Resistance Boxes 596
Resistance Tester, Ground 930
Resistance Thermometer Elements 158
Resistance Thermometers, Fused-in-glass 250
Resistance-thermometer Bulbs 1030
Resistance-thermometer Element for Air Ducts 474
Resistivity Apparatus, Gish-Rooney-type 487
Resistor Assortments 271
Resistor, Combination WW and Carbon 1055
Resistor, Wire-wound 498, 948
Resistor-testing Bridge, Line-operated 196
Resistors 710
Resistors, Fine-winding 838
Revision of Thermocouple Tables 27
RF Wattmeter 935
Rheostat, Aircraft Temperature-control 838
Rheostat Knob-shaft 946
Rocket Instrumentation 399
Rocketry, Instrumentation For Exterior Ballistic Research In 184
Rotameter Adapter for Horizontal Lines 1055
Rubber Processing, Instrumentation in 723

S

Sample Carrier, Radioactive 385
Sampler, Atmospheric 484
Sand Washer 1167
Saving $1600 per Valve Installation 236
Scale, Batch 478
Scale, Hydraulic 827
Scale and Template, Combination 390
Scaler 939
Scaler, All-purpose 492, 938
Scaler, Portable Battery-operated 492
Scaler, Radioactivity 275
Scaler and Register, Scale-of-ten 168
Scalers, Basic Unit 1042
Scales, Hydraulic Crane 42
Schlieren Light Source 807
Screen, Phosphorescent 393
Screen Rooms, Pre-built 486
Screw Driver with Built-in Flashlight 426
Seismograph Instruments, Miniature 478
Seismograph, Pulse Magnetic 169
Servomechanism Kit, Educational 691
Servomotor, Small 256
S. G. Controllers, Industrial-liquids Densitometers and 252
Shaker and Power Supply 1270
Shear-hardness and Diamond-scratch Tester 599
Shield, Radioactivity 385
Shock Absorber, Pipe-line 271
Shock-testing Machine 483
Shooting an Electronic Circuit 450
Shop Layouts, Instrument 401
Shunts, Switchboard Type 709
Shutoff Valve 53
Sight Reading of Orifice Meter Charts 907
Signal Calibrator 107
Signal Generator, FM 374, 380
Signal Generator, VHF 376
Signal System for Hazardous Locations, Multiple 256
Signal Tracer 50
Ski Jumpers Timed at 50 MPH at Take-off 454
Slide Rule, Chemical-problems Circular 264
Slide Rule, Log Log 702
Slide Rule, Ohm's Law 389
Slide Rule for Radioactivity, Circular 498
Slide Rule for Relief Valve Sizing, A 452
Slide Rule, Statistical & Quality-Control 51
Slide-rule, Productivity 590
Slide-rule Settings for Use in Measured-mesh Work 285
Slight Alterations of a Standard Hygrothermograph Cut Costs 241
Smoke Density Indicator 52
Smoke Detector, Photoelectric 1048
Smoke Indicator, Photoelectric 929
Snap Switch, One-way Momentary-contact 1283
Snap Switches, Small 942
Snap-gage Converter 370
Soldering Gun 1048
Solenoid Valves 54
Solution Conductivity Measurement 664
Some Considerations in the Application of Instruments to the Pulp and Paper Industry 144
Sorter, Metal 687, 921
Sorter, Tile 264
Sound Probe 42
Spectrographic Analysis for Water Conditioning 460
Spectrometer, Double Monochromator and 580
Spectrometer, Infrared 686
Spectrometer, Precision 159
Spectrophotometer, Infrared 564
Spectrophotometric Equipment Installed at Princeton 1286
Spectrophotometry 522
Speed Changers, Miniature 496
Speed Control and Speed Proportioning System, Dual Automatic Motor 468
Speed Control and Synchronization of Multi-unit Internal Combustion Engine Plants 1244
Speed Control System, Motor 267
Speed Controller for Electric Motors 827
Speed Indicator, Average 158
Speed Proportioning System, Dual Automatic Motor Speed Control and 468
Speed-control Clutch, Automatic 462
Speed-control System 599
Sphygmomanometers, An Analysis of 1134
Square-root Planimeter Method, Calculation of Orifice Meter Charts by the 1081
Square-wave Generator 375
Standard of Neutron Intensity, A Permanent 249
Standards, Permanent Gloss 463
Starters Motor, Solenoid 43
Static Eliminator for Analytical Balances 587
Statistical & Quality-Control Slide Rule 51
Stopcock Adapter 706
Storage Battery, Small-size Silver-type 270
Strain Computer, Principal 584
Strain Indicator 367
Strain Recorder 688, 1148
Strain-gage Dynamometers and Indicators 445
Strain tester for Elastometers 157
"Stretchmeter" for Materials in Process 1268
Strips, Wire-labeling 709
Stuffing Box for High-pressure Orifice Meters 802
Sulphur Dioxide Recorder 41
Surface Plate with Inspection Microscope and Illuminators 44
Survey Detector, Gamma- 171
Survey Indicator, Gamma 170
Survey Instruments, Radioactivity 1277
Survey Meter, Portable Radioactivity 1277
Survey Meter, Radioactivity 822
Survey-type Magnetometer 467
Sweep Generator 931
Sweep-generator-output Adaptor 167
Sweep-signal Generator 491
Switch, 48-operation Time 479
Switch, High-speed Multichannel Sampling 815, 1028
Switch, High-temperature 389
Switch, Magnetic Proximity 708
Switch, Manual Preset Time 1267
Switch, Midget-Snap-action 1056
Switch, Photoelectric 382
Switch, Precision 390, 602, 707, 708
Switch, Pressure-actuated 478
Switch, Roller-plunger-operation Precision 1169
Switch, Rotary Snap 708
Switch, Snap-action 707
Switch, Splash-proof Precision 833
Switch, Time 1269
Switches, Mercury 708
Switches, Pressure 833
Switches, Selector 833
Synchronization of Multi-unit Internal Combustion Engine Plants, Speed Control and 1244

T

Tablet Disintegration Tester 265
Tachometer, Chronometric 802
Tachometer, Dual-range 1266
Tachometer, Electric Hand 926
Tachometer, Electronic Counter-type 1044
Tachometer, Hand 695, 1047
Tank-Filling Control Ends Costly Spillage-waste, Speeds Operations 239
Tape, Adhesive Label 1279
Tape Labeling 709
Tariff Cuts, Protect American Instruments Against 895
Tariff and Instruments, The Proposed 1009
Teaching of Process Control Principles To Chemical Engineers, The 557
Technical Societies 84, 394, 856, 1059, 1170
Telemeter, Tank-gaging 366
Telemetering, Pressure Pickup for 160
Telemetering, Some Design Considerations in Connection With the Use of High Speed Thermometry for 1298
Telemetering System, An FM/FM 247
Telemetering System, Long Range Multi Channel 70
Telescope, Instrument-reading 1030
Telescope, Pocket 702
Temperature Bath, Constant 804
Temperature Control Unit, Fluid 1266
Temperature Controller 41, 918
Temperature Controller, Air-operated Indicating 1152
Temperature Controllers, Self-operated 804
Temperature Indicators and Recorders 1148
Temperature Indicators, Thermoelectric and Resistance 40
Temperature Measurement and Control in the Process Industries 240
Temperature Measurement, Dynamic Accuracy 66
Temperature and Pressure Instruments 580
Temperature Recorder, Multi-channel 916
Temperature Recorder, Portable 250, 1028
Temperature Recorder-Controller 918
Temperature Recorders, Pressure and 472
Temperature Regulator 254
Temperature Unit, Controlled 1266
Temperature Work at M.I.T., Low 1286
Temperature-control Systems, Input Control Unit for 41
Temperature-limit Cut-out 156
Template, Combination Scale and 390
Ten-equation Electrical Computer 252
Tensimeter, Concepts of Instrumentation as Taught at The University of 34
Tensiometer, Paper 372
Tension Meter 263
Terminal Block 708
Terminals for Precision Switch, Front-facing 1282
Test Apparatus, Latex Stability 1270
Test Apparatus With Program Control, Humidity temperature 262
Test Core Maker, Transverse 1043
Test Set, TV, FM and AM 818
Test-tube Rack 704
Tester for Amplifiers, Multi-purpose 817
Tester, Batters 820
Tester, Battery-cell 578
Tester, Bearing-grease 369

Flexible Valve Corp. 165
Research Engineering Corp. 162
Johnson, Roy 281
Johnson Corporation 164
Nuclear Instrument & Chemical Corp. 168, 275, 385, 387, 492, 498, 822, 824,
Skinner Chuck Company 942
Sola Electric Company 594

Tester, Brake-lining 466
Tester, Circuit 48
Tester, Crankcase Oil 924
Tester, Dual-operated Insulation 167
Tester, Electron-tube 815
Tester, Film-adhesion 162
Tester, Fluorescent-fixture 812
Tester, Foundry Sands 924
Tester, Hearing-aid-battery 1161
Tester, High-pressure Hose 924
Tester, Ignition-harness 376
Tester, Insulation 269, 592, 699, 1036
Tester, Laboratory Tube 811
Tester, Machinability 162
Tester, Multi-purpose Electrical 165, 486, 491, 598, 699, 813, 1036
Tester, Multi-purpose Electrolysis and Corrosion 1162
Tester, Oven-temperature 44
Tester, Production-line Insulation 268
Tester, Sand-permeability 808
Tester, Soil and Ground Resistance 811
Tester, Tablet Disintegration 264
Tester, Transverse Core 1042
Tester, Voltage 597
Testers, Earth-resistivity-type, Ground 49
Testers, Insulation Breakdown 812
Testing Instruments, AM-FM-TV 262
Testing, Instruments In Rail Transportation 1307
Testing Machine, 60,000-lb. 164
Testing Machine, 10,000 lbs. 265
Testing Machines, Creep 469
Testing Machines, Universal 691
Testing by the National Bureau of Standards 454
Testing-machine Jaws 1043
Thermocouple Assemblies, Fast-response 802
Thermocouple, Molten-metal 804
Thermocouple, Molten-steel 800
Thermocouple Tables, Revision of 27
Thermocouple Wells 694
Thermoelectric Pyrometry, Millivoltmeters for 256
Thermometer, Dial 260, 804
Thermometer, Platinum 686
Thermometer, Pocket 1266
Thermometer Testing Set 802
Thermometers, Fused-in-glass Resistance 259
Thermometers, Resistance 686
Thermoregulator 261
Thermoscopic Lacquer 948
Thermoscopic Pellets, Crayons and Paints 42
Thermostat, Aircraft 588
Thermostat, Immersion 692
Thermostat, Miniature 40
Thermostat-controlled Logarithmic Attenuator 487
Thermostats 42
Thermostats, Bimetal 695
Thickness Gage 810
Thickness Gage, Coating 156
Thickness Gage, Continuous 370, 689
Tile-Setter 264
Time Cycle Controllers 254
Time Recorder 372
Time-delay Relays, Pneumatic 694
Time-interval Recorder 257
Time-Saving Auxiliary Instrument, A 240
Time-temperature Controller for Dyeing Processes 156
Timer, Audible-signal Darkroom 600
Timer, Automatic 481, 600, 694, 696, 808
Timer, Automatic Interval 1268
Timer, Automatic Process 692
Timer, Dual Sequence 254
Timer, Duplex Cycle 924
Timer, Electric Interval 1267
Timer, Electronic 1268
Timer, Interval 696, 811
Timer, Millisecond 254
Timer, Resetting Delay 922
Timers, Hermetically-sealed 600
Timing Controllers, Two-circuit 160
Timing Motor 50, 600, 1049
Timing Motors, Standardizing A-c. 694
Timing Relay, Electropneumatic 173
Tissue Embedding Apparatus 832
Torch, Hand 704
Torque Motor 1151
Torsion Test, The Use of the 564
Totalizer and Control-action Generator, Pneumatic 1150
Tracer for CRO Patterns, Optical Viewer 810
Tracer, Signal 50
Tracers Used to Study Plating Process, Radioactive 434
Training, Instrument Mechanic 281
Training Program, Instrument Repairman Trade Apprentice 280
Time Switches 263
Transducers, Variable Transformer-ratio 369
Transformer, Differential 610
Transformer, Variable 388
Transformer, Voltage-adjusting 815
Transformers and Chokes 1052
Transformers, Control 55
Transformers, Explosion-proof Variable 812
Transformers, High-accuracy Indoor Current 156
Transformers, Miniature 600
Transformers, Special-application Reactors and 390
Transformers, Tap Changing 1052
Transformers, Variable 812
Transmission Measuring Set 1159
Transmission with Reverse, Variable-speed 810
Transmission Systems, Dial Indicators for 159
Transmission Test Set, Multi-purpose 930
Transmitter, Flow-rate 920
Transmitter, Pressure 156, 479
Transmitters, Liquid-level 684, 802
Triodes, Medium-mu Twin 834
Truck Motor Endurance-Test Instrumentation 156
Tube, Double-triode Subminiature 711
Tube, Fitting, Flareless 592
Tube Flaring Tool 1056
Tube, Oscilloscope 714
Tube Tester Kit 1161
Tube Testers, Electron 485
Tubes, Industrial Electron 172
Tubes, Subminiature Amplifier 173
Tubing, Instrument 837
Tubing Reducer 707
Tumbler-mixer 1273
Turbidimeter, Recording 686
TV Alignment Marker 373
TV Calibrator 936
Two-rotor Type of Positive-displacement Liquid Meter, The 409

U

UHF Filter 838
UHF Measurements, Slotted Line and Coaxial Elements for 593
Ultra-microtome 41
Ultraviolet Lamp, Portable 702
Ultraviolet Lamps 1257
UNESCO and the Instrument Industry 1008
Users' Requirements for Control Valves 806
UV Source for Oil Prospecting 703

V

Vacuum Diffusion Pump, High 270, 272
Vacuum Gage 41
Vacuum Gage, High 260
Vacuum Pump 828
Valve, Adjustable-characteristic 942
Valve, All-glass Overflow Check 826
Valve, Automatic-reseat Relief 706
Valve, Ceramic-body Control 255
Valve, Diaphragm-motor 826, 1051
Valve, Diaphragm-motor Pinch-type Flexible-wall 165
Valve, Electrohydraulic Motor 1051
Valve, 4-way 942
Valve, High-pressure Reducing 387
Valve, Hydraulic Relief 488, 941
Valve, Long Sweep D-in. Angle 1050
Valve, Magnetic Air 827
Valve, Non-lubricated Cylindrical Control 165
Valve, Packless Needle 1059
Valve, Rubber-lined 826
Valve, Shutoff 53
Valve, Solenoid 164, 942
Valve, Solenoid Hydraulic 941
Valve, Steam-jacketed Flow-control 826
Valve, Time-delay 478
Valve, Two-pressure Hydraulic 54
Valve-Sizing for Individual Applications 341
Valves, Check 1049
Valves, Diaphragm-pinch 53
Valves, Four-way Solenoid 705
Valves, Gage 705
Valves, Instrument-piping 1281
Valves, Miniature Flow 941
Valves, Piston-operated 941
Valves, Relief 705
Valves, Rubber-seated 495
Valves, Solenoid 54
Van Slyke Blood Gas Apparatus 1156
Variable Transformer-ratio Transducers 369
Variable-speed Drives, Combination 1279
Variable-speed Pulley 830
Variplotter, X-Y Recorder 252
Vibration Field Test Engineer, Instrumentation Problems of the 142
Vibration Isolators 496
Vibration Micrometer 687
Vibration Test Stands 164
Vibration-fatigue Tester 368
Vibration-strain Analyzer 372
Viscometer, Adapter 1166
Viscometer for Explosion-proof Applications 1270
Viscosimeter, Automatic 477, 478
Viscosimeter, Nylon-size 804
Viscosity Controller, Automatic 250
Volt-ammeter, Pocket 701
Voltage Divider 946
Voltage Divider, Low-torque 944
Voltage Divider, Miniature Multi-turn 1282
Voltage Divider, Precision 1284
Voltage Reference Standards 696
Voltage Regulator 43
Voltage Regulators, Feeder 590
Voltage Supply, Regulated A-c. 594
Voltage Tester 597
Voltage-dividing resistors 391
Voltmeter, Miniature 373
Voltmeter, Vacuum-tube 698
Voltmeters, Electrostatic 817
Volt-ohmmeter, TV 267
Volt-ohm-mil-ammeter 166

W

Warning Signs, Radioactivity 824
Water Baths, Laboratory 42, 43
Water Conditioning, Spectrographic Analysis for 400
Water Softener, Automatic 337
Weather Hook-on 698
Waveform Monitor for TV Transmitters, R-f 376
Wear Test for Automotive Gear Lubricants 248
Weather-resistance, Accelerated-test Equipment for 806
Welding Controllers, Resistance 43
Western Europe, Report on 657, 778, 906
Wiring Terminal Lugs 269
"World's Smallest" X-ray Tube 276

X

X-Ray Diffraction Patterns, A "Photomicrometer" for Measuring 400
X-Ray Gaging Systems 1045
X-ray Microscope 840
X-ray Tube, "World's Smallest" 270
X-Y Coordinate Millivolt Recorder, Automatic 338
X-Y Recorder 252

Author and Source Index

A

A. A. A. Valve Company, Inc. 54
Abart Gear and Machine Co. 1048
Abbeon Supply Company 478
Ace Engineering and Machine Co. 48
Acme Metal Die, Inc. 390
Acragage Co. 1264
Acro Mfg. Company 1056
Advance Electric and Relay Co. 944
Aerovox Corporation 55, 710, 711
Aget-Detroit Company 50
Airborne Instrument Laboratory 1036
Aircraft Electronics Associates, Inc. 166
Aircraft Fitting Company 392
Aircraft-Marine Products, Inc. 839
AiResearch Manufacturing Co. 364
Alden Products Inc. 1109
All American Tool & Mfg. Co. 44, 368
Allen-Bradley Company 43, 162, 173
Allied Control Co., Inc. 56, 488
Allied Radio Corporation 264
Allis Chalmers Manufacturing Co. 599
Alloy Bellows Engineering Co. 1044
American Chain & Cable Co. 41, 1152
American Engineering Company 485
American Instrument Co. 156, 262, 691, 695, 804, 805
American Optical Company 41, 376, 482, 582, 921, 1153, 1155, 1156
American Paulin System 684
American Phenolic Corporation 392
American Recording Chart Co. 384, 692
American Standards Association 1286
American Time Products, Inc. 806, 1159
American Type Founders 836
Amperex Electronic Corp. 270
Amplifier Corp. of America 489, 593
Analytical Measurements, Inc. 688
Andresen, Jack 347
Angell, Robert F. 853
Applied Science Corp. of Princeton 815, 1028
Aquadyne Corporation 257
Ark-Les Switch Corp. 708
Arma Corporation 157, 369, 582, 593
Assembly Products, Inc. 256, 918, 922, 1053, 1153
Associated Research, Inc. 49, 811, 812
Astron Corporation 836, 838
Atlas Electric Devices Co. 806
Atlas Valve Company 587, 942
Atomic Instrument Company 168, 393, 824, 939
Audio Instrument Company 937
Autovall Company 493, 1051
Automatic Control Company 483
Automatic Electric Mfg. Co. 479
Automatic Temperature Control Co., Inc. 922, 1267
Autotron Company 1044

B

Bachrach Industrial Instrument Co. 260
Bailey Meter Company 800
Baird Associates 261
Baker Company 710
Baker, H. H. 238
Baldwin Locomotive Works 162, 164, 367, 690, 1148
Ballard, R. G. 1006
Barber Coleman Company 164, 264, 474, 588, 826, 828
Barksdale Valves 705, 942, 1164
Barry Corporation 485, 1283
Barstow, O. E. 396
Barton Instrument Corp. 157
Bausch & Lomb Optical Company 807
Beckman, Inc., A. O. 1028
Beckman & Whitley, Inc. 916
Behar, M. F. 129, 235, 335, 441, 551, 777, 895, 997, 1235
Bendix Aviation Corp. 160, 1174
Bendix Research Laboratories 466
Berger Scientific Supplies, Inc. 828
Berkeley Scientific Co. 487, 492, 692, 932, 1266
Berkshire Laboratories 375, 1038
Bertz Co., Inc., Otto 710
Berry, Howard L. 256
Berry, T. M. 345
Beta Electric Corporation 47
Bitterman, L. M. 184
Biddle Company, James G. 167, 268, 489, 592, 699, 930, 1047
Blom, Edward C. 903
Bock Engineers, R. G. 590
Boeckeler Instrument Company 265
Bohn, M. J. 614
Bonnton Radio Corporation 380
Boothe, Kenneth B. 1186
Borg Corporation, George W. 602
Bowers, Walter S. 1188
Bradley Laboratories, Inc. 55, 709, 711, 835
Bristol Company, The 1148
Bristol Motor Company, The 1049
Brookfield Engineering Labs., Inc. 250, 1166
Brooks Rotameter Company 688
Brown Electro-Measurement Corp. 933, 934
Brown, R. J. 723
Brown, R. M. 144
Browning Laboratories, Inc. 385, 598, 926
Brush Development Company 262, 814
Buckeye Plastic Corp. 1046
Buffalo Meter Company 916
Buhl Optical Company 40, 704, 1031
Builders-Providence, Inc. 159
Burnmaster, Kenneth E. 242
Burrell Corporation 948, 1156
Bush Associates, G. F. 157, 924

C

Cady & Company, E. J. 44
Caldyne Company, The 1270
California Institute of Technology
Campbell Company, J. A. 1164
Canton Electric Development Co. 83
Carlson, George R. 399
Carnegie-Illinois Steel Corporation
Cash Valve Mfg. Corp., A. W. 706
Central Research Laboratories, Inc.
Central Scientific Company 498,
Chaplin, Allen L. 38, 152, 342
Chatillon Electronics Corp. 166, 380
Chemitupp Company 164
University of Chicago 1174
Cinema Engineering Company 944
Cisar, Janet M. 940
Clare & Company, C. P. 387, 392
Clarke Instrument Corp. 48, 53,
Clarkstan Corporation 471, 828,
Clarostat Manufacturing Co., Inc.
929, 946, 1055, 1165
Clarridge, R. F. 1248
Clifford Mfg. Company 1284
Clifton, Donald E. 1307
Cloudy Brenagle Company 375
Coggeshall, Norman D. 552
Cole Instrument Company 596, 700,
Coleman Instruments, Inc. 264, 474,
Comar Electric Company 707
Combustion Control Corp. 42, 371,
830, 929
Commonwealth Edison Company 1018
Como-Tew Company 42
Comax Sales Company 684
Condenser Products Company 820,
Condor Radio 1042
Conoflow Corporation 595, 942
Conover, Richard E. 445
Consolidated Engineering Corp. 472,
Control Engineering Corp. 802
Control Products, Inc. 390
Cook Electric Company 690
Cook Research Laboratories 810
Cooley Electric Manufacturing Corp.
Cope, J. H. 621
Cornell-Dubilier Elec. Corp. 711, 1054
Costelloe, J. T. 1081
Cosa Corporation 482
Cowles, Jr., D. B. 904
Cramer Company, R. W. 924, 1268
Crawford Fitting Company 1051
Curtis Development & Mfg. Co. 708
Cuthbert, J. H. 280

D

Datco Instruments, Inc. 694
Daven Company 1036, 1284
Daves, Richard S. 350
Davis Emergency Equipment Co.
1271
DeBoer, W. 404
Deep-freeze Distributing Corp. 1270
Detecto Scales, Inc. 478
Dice Company, J. W. 687
Dietert Company, Harry W. 266, 696,
Dillon and Company, Inc., W. C.
Dimco-Gray Company 160
Distillation Products Industries 200,
272
Dix-hek and Walker 921
DuMont Laboratories, Allen B. 45,
818, 1036, 1038
Duncan, D. S. 670
Duraknod, Inc. 600, 708
Durant Manufacturing Co. 157, 1269

E

Eagle Signal Corporation 692
Eastern Industries, Inc. 272
Eberbach & Sons Company 474
Ebert Electronics Corp. 836, 1282
Eder Instrument Company 44
Edin Electronics Company 366,
Edsel, W. W. 448
Electric Hotpack Company, Inc. 371,
Electrical Facilities, Inc. 592
Electro Products Labs., Inc. 687, 702,
Electro-Mec Laboratory 944
Electrofin Apparatus Corp. 944
Electronic Associates, Inc. 252, 264,
Electronic Instrument Co., Inc. 1161,
1275
Electronic Measurements Corp. 266,
Electronic Systems Company 492
Electronic Tube Corporation 45, 372,
Electronic Workshop, Inc. 1275
Elgin National Watch Co. 1264
Elitron, Inc. 489
Elwood Company 597
Emberson, M. A. 236
Emmett Machine & Manufacturing Co.
Enco Manufacturing Co. 393, 946
Engineering Research Associates, Inc.
Engle, Inc., J. A. 807
Equipoise Controls, Inc. 1266
Ereona Corporation 1155
Ess Instrument Company 273
Evans, Ernest C. 242
Exhibit: Supply Company 942, 1283
Experimental Engineering Corp. 1169
Ewald, Phillip 34

F

Fairchild Camera & Instrument Corp.
254, 595, 703, 1264
Fairchild Recording Equipment Corp.
Farmer Electric Company 1268
Farr Company 706
Farrand Optical Co., Inc. 580
Farris Starcon Corp. 804
Faull, Harry A. 957
Feiler Engineering Company 699
Ferranti Electric, Inc. 484, 485
Fink, R. C. 904
Fischer & Porter Company 252, 256, 580, 582, 584, 684, 802, 804, 1055, 1152,
Fisher Scientific Company 43, 260,
477, 574, 704
Fitzgerald, Frank R. 286
Fluidyne, Inc., Fredric 479
Flashback Sales 283

Flexible Valve Corp. 165
Flight Research Engineering Corp. 162
Forster, Jr., George H. 1311
Fuhrer Company 156
Frazier & Sons 600
Fromm, Marvin M. 239, 452
Fuller, David H. 246
Fulton Sylphon 1050
Furst Electronics 385, 594

G

Gardner Scientific Corp. 159, 808, 922, 1032
Gale Dorothea Mechanisms 481
Galley, Robert L. 341
Gamewell Company 838
Gardner Laboratory, Inc., Henry A. 41, 42, 162, 164, 366, 587, 692, 810, 927, 1032, 1034
Gaunt Industries 44
Geer, Roger L. 186
Gelber Company, Samuel S. 929
General Electric Company 40, 43, 44, 52, 157, 158, 167, 171, 372, 390, 454, 456, 482, 489, 496, 572, 588, 598, 600, 602, 686, 698, 807, 808, 817, 824, 840, 927, 935, 937, 1028, 1034, 1036, 1047, 1140, 1151, 1174, 1274
General Electric Research Laboratory 407
General Electric X-Ray Corp. 1267
General Radio Company 374, 378, 474, 488, 593, 698, 700, 1150, 1158, 1160, 1276
General Scientific Equipment Co. 378, 704
Geophysical Instrument Company 382, 487
Gerdes, W. F. 72
Gertsch Products, Inc. 376, 697, 810
Gidding & Lewis Machine Tool Co. 1266
Givens, Homer C. 1244
Glass Engineering Labs. 273
G. M. Manufacturing Company 916
Gordon Co., Claud S. 41, 272, 807, 808, 924, 1042, 1043, 1165, 1167, 1271
Gotham Instruments 685, 800
Grace, Jr., E. J. 1070, 1074
Graham, O. W. 1074
Gray, Joseph B. 557
Grayhill 388
Green Instrument Company 703
Greiner Company, Emil 41, 478, 694, 706, 828, 1156, 1283
Grozinski, Paul 243
Guardian Electric Manufacturing Co. 601
Guenther Instrument Co. 158
Gulf Oil Corporation 946

H

Haas Corporation 45
Hadley Associates, Inc., H. A. 1271
Hazard Corporation 1150, 1269
Hall Laboratories, Inc. 469
Halldorson Company 815
Halross Instruments Corp., Ltd. 602
Hammel-Dahl Company 53, 1056
Hanau Engineering Co., Inc. 1166
Hand, T. R. 336
Hapel, William J. 552
Hard, Carl G. 344
Hardwick-Hindle, Inc. 710
Harshaw Chemical Company 480
Hartnett, J. A. 337
Hartung, C. A. 450
Hassins Turner Company 1267
Hastings Instrument Co., Inc. 41, 366, 802
Hathaway Instrument Co. 584
Haydon Company, A. W. 600, 694, 830
Haydon Manufacturing Co., Inc. 600, 696, 811
Hays Corporation 474
Hays, James 853
H-B Instrument Company 261
Hellrot Corporation 1282, 1284
Hendricks, J. E. 351
Heri Buts Electric Company 1052
Hewlett-Packard Company 373, 376, 378, 379, 382
Hickok Electrical Instrument Co. 486, 811
Hills, C. W. 140
Hofman Laboratories, Inc. 45
Hoge, A. W. 132
Hoke, Inc. 367, 368
Johns Hopkins University 841
Hornaday, G. F. 132
Horton, Billy M. 1005
Huggins Laboratories 160
Humidial Company 586
Hunter Spring Company 806, 835
Hydroway Scales, Inc. 42, 827

I

Ideal Industries, Inc. 812
Illinois Institute of Technology 570
Indiana Steel Products Co. 694
Inductograph Products 384
Industrial Control Company 814, 1040, 1148
Industrial Devices, Inc. 48, 373, 709, 835
Industrial Electronics, Inc. 167
Industrial Instruments, Inc. 380, 809, 839, 946
Industrial Timer Corp. 254, 696
Industrol Corporation 484
Instron Engineering Corp. 1043
Instrument Development Laboratories 250, 486
Instrument Laboratories 47, 165
Insilline Corp. of America 946
International Instruments, Inc. 48, 1273
International Microscope and Art Co. 1032
International Rectifier Corp. 271, 837
International Register Company 50, 263

J

Jackson Electrical Instrument Co. 1638
James-Pond-Clark 1049
Jarsson Gage Company 387
Jasper, Norman H. 142
Jessen Co., Inc., G. D. 826
Jerguson Gage & Valve Co. 705, 1281
Jet Bell Products Co., Inc. 708
Johnson, Roy 281
Johnson Corporation 164
Johnson Service Company 918, 941
Johnston, Charles B. 358
Jorgensen, B. C. 72

K

Kahl Scientific Instrument Corp. 686
Kalbfell Laboratories, Inc. 487, 817
Karpark Company 804
Kates Company, W. A. 1269
Kay Electric Company 158, 373, 388, 931, 933, 1034
Keithley Instruments 934
Kell, John A. 240
Kelly, R. D. 136
Kelley-Koett Manufacturing Co. 470, 822, 824, 1277
Kennedy, W. J. 1082
Kepco Laboratories, Inc. 820, 931, 1042, 1275
Kling Engineering Corp. 159, 826
Kinney Manufacturing Co. 828
Kirk, David B. 1191
Kollmorgen Optical Corp. 1030
Koopman, R. J. W. 596
Kortund Company 496
Kratz, Design, Inc. 680
Krohn-Hite Instrument Company 485, 928, 1052, 1054
Krouse Testing Machine Co. 44

L

L. A. B. Corporation 164
Labelon Tape Company 709
Lambe, E. P. 670
LaPine & Company, Arthur S. 704, 710, 1273
Lapp Insulator Company 40
Lawler Automatic Controls, Inc. 254
Leach Relay Company 836
Lear, Inc. 268, 586, 690, 940, 1032
Leeds & Northrup Company 41, 250, 390, 596, 697, 1148, 1264
Link Aviation, Inc. 678, 1160
Link Engineering Company 588
Liston-Folb 698
Little, Inc., Arthur D. 1271
Lloyd Manufacturing Co. 51
Loewen, Erwin G. 560
Long, Theodore M. 257
Lovins Engineering Co. 1042, 1280
Lynch, John F. 1125

M

Macbeth Corporation 1154
MacDonald Company, W. S. 686, 1030
MacGeorge, W. D. 610
Machlett & Son, E. 587, 929
Mahlmeister, Louis 616
Mallory & Co., Inc., P. R. 268, 274, 703
Manning, Maxwell, & Moore, Inc. 1148
Marion Electrical Instrument Co. 267, 814
Marvel Engineering Company 493
Marzolf, J. M. 562
Massa Laboratories, Inc. 1280
Massachusetts Institute of Technology 568, 1286
Master Equipment Corp. 706
Maxson Corporation, W. L. 390, 496, 604, 707, 708, 823, 1160, 1169, 1282
Mayo-Wells, W. J. 717
McCulpin-Christie Corporation 820
McCullough, G. W. 28
McDonnell & Miller, Inc. 368
Measurements Corporation 599, 1162
Meletron Corporation 478, 498
Mengel, John T. 70
Menlo Research Laboratory 1043
Metron Instrument Co. 496, 926, 1279
Metrotype Corporation 158
Michigan State Highway Department 454
Michigan Tool Company 588
Micro Switch 492, 495
Microchemical Specialties Company 366
Midwestern Geophysical Laboratory 1040
Miller, M. C. 1162
Miller Motor Company 692
Millivac Instruments 593, 814, 1036, 1161, 1264
Milton Roy Company 684, 1266
Mine Safety Appliances Company 364, 484
Minneapolis-Honeywell Regulator Co. 41, 156, 157, 165, 387, 472, 474, 580, 591, 694, 800, 802, 805, 1049, 1264
Minter, Clarke C. 1134
Mitchell, S. E. 249
Modern Metalcraft 157
Modernair Corporation 686
Moisture Register Company 43, 478, 692
Moore & Company, Samuel 837
Moore Products Company 252
Morton, Henry I. 338
Murphy & Co., Inc., Jas. A. 706

N

National Aeronautical Corp. 482
National Bureau of Standards 27, 248, 249, 454, 459, 466, 463, 467, 469, 572, 680, 1016, 1020, 1022, 1136
National Paint, Varnish and Lacquer Assn. 159, 464
National Tool Company 250
National Tube Company 469
Naval Ordnance Laboratory 462
Neomatic, Inc. 1053
Neon, Inc. Claude 691
Neptune Meter Company 686
New Hermes, Inc. 691, 1046
Newage International, Inc. 924
Nichols, N. B. 66
Nichols, R. L. 461
Niles-Bement-Pond Company 370, 371, 689, 828, 1045, 1277
Nilson Gage Company, Inc. 45, 391, 480, 481, 827
Nolte, Claude B. 79, 1300
Norcross Corporation 1270
North American Manufacturing Co. 53
Northwestern University 454, 456
Novak, A. V. 1128
Nuclear Instrument & Chemical Corp. 168, 275, 385, 387, 492, 498, 822, 824, 930, 932, 940, 1163, 1277
Nuclear Measurements Corp. 170, 274, 386

O

Obetheltman, L. E. 508
Ohmite Manufacturing Company 271, 389, 946
Oregon Electronic Manufacturing Co. 702

P

Pacific Universal Products Corp. 810
Pako Corporation 1266
Palmer Thermometers, Inc. 804
Panalarm Products, Inc. 256, 366
Panellit, Inc. 1056
Pan-technics, Ltd. 702
Pantex Manufacturing Corp. 498, 705, 941
Parker Appliance Company 707, 1056
Partridge, F. M. 189
Pasaic Analytical Labs. 494
Penn Industrial Instrument Corp. 472, 685, 1028
Pennsylvania Flexible Metallic Tubing Co. 588
Perkin-Elmer Corporation 364, 686
Phillips Petroleum Company 252
Photo Research Corp. 695, 922
Photographic Products, Inc. 255, 809
Photoswitch, Inc. 52, 382, 694, 832, 928, 1048, 1278
Photovolt Corporation 924, 929
Photron Instrument Company 266
Pickett & Eckel, Inc. 51, 702
Pigott, J. S. 1240
Podhelniak, Inc. 1028
H. K. Porter, Inc. 1167
Potter Aeronautical Company 920
Potter & Brumfield 602, 834
Potter Instrument Co., Inc. 156, 167, 479, 1044
Potter, J. H. 448
Powers Regulator Company 826, 1051
Precision Apparatus Co., Inc. 262, 491, 818
Precision Radiation Instruments, Inc. 386
Precision Scientific Company 57, 369, 587, 809, 831, 832, 1264, 1270
Precision Thermometer & Instrument Co. 504
Pressure Products Corporation 704
Princeton University 1286
Product-on Instrument Co. 159, 262, 481, 812, 1044
Pyramid Instrument Company 701, 1276

Q

Quality Control Company 260

R

Radiation Counter Labs., Inc. 168, 171, 275, 385, 822, 824, 938, 939, 1163, 1164
Radio City Products Company 50, 490
Radio Corp. of America 56, 57, 166, 169, 172, 270, 382, 391, 474, 580, 711, 813, 820, 834, 936, 942, 946, 1036, 1159, 1168, 1273, 1274
Radioactive Products, Inc. 169
Rapidesign, Inc. 390
Raytheon Manufacturing Co. 710, 711
Reed Research, Inc. 935, 1264
Renfrew, Paul 409
Republic Flow Meters Company 916
Research Appliance Company 472
Research Control Instrument Co. 941
Revco, Inc. 810
Richardson-Allen Corp. 702
Riggio, V. A. 236, 337, 341, 346
Rimat Machine Tool Company 263
Rimbach, Richard 657, 778, 895, 906, 1008, 1069
Rivett Lathe & Grinder, Inc. 472, 941
Robinson, Inc., Edward E. 690, 1268
Rockwell Manufacturing Co. 802, 830
Rockwell, Ralph A. 1252
Rohm & Hass Company 367
Rose, E. H. 504
Rosen & Associates, S. 364
Rosenthal, Robert 664
Ross, Harry 252
Ross Operating Valve Company 478
R-S Products Corporation 271, 495, 826
Rudolph & Sons, O. C. 808
Rueger, Herman 340, 342
Ruge-deForest, Inc. 158

S

Santa Anita Engineering Co. 704
Sarco Company, Inc. 1051
Sargent & Company, E. H. 40, 42
Saturn Electronic Company 926
Saxl Instrument Company 263
Schaevitz Engineering 488
Scherr, Inc., George 591
Schuler, Albert E. 908
Science Kits, Ltd. 822
Scientific Glass Apparatus Co., Inc. 829
Scientific Instrument Company 1152
Seely Instrument Company 54
Seismograph Service Corp. 160
Selas Corp. of America 580
Sell Electric Co., H. H. 1276
Service Recorder Company 372
Servo-Tek Products Company 256, 367, 408, 694
Servomechanisms, Inc. 378
Sotheo 1162
Shallcross Manufacturing Co. 488, 697, 700, 710, 833, 834, 930, 948
Shand and Jurs Company 306
Sharples Corp., The 1031
Shaw, Milton C. 560
Sheffield Corporation 44, 482, 808, 1045, 1046, 1055, 1279
Shellenberger, W. H. 896
Sherman, George W. 31
Siddons, George F. 1105
Sierra Electronic Corporation 920
Sigma Instruments, Inc. 1053, 1281
Silge & Kuhne 690
Simpson Electric Company 933, 1158
Skinner Chuck Company 942
Sola Electric Company 594
Sorenq Manufacturing Corp. 833
Sorensen & Company, Inc. 696, 701, 829
Sostman, Henry 36
Sound Apparatus Company 920, 1148
Southwestern Industrial Electronic Co. 477, 478
Soyster, Chas. J. 285
Specialties, Inc. 166, 493
Spellman Television Corp. 1032
Spencer-Kennedy Laboratories, Inc. 106, 700, 816
Sperry Products, Inc. 390
Sprague Electric Company 57
Sprague Engineering and Sales 924
Sprague Products Company 700
Sprengnether Instrument Co. 160
Square D Company 43, 827
Standard Gage Company, Inc. 370
Statham Laboratories, Inc. 1030
Stebar Company 1278
Sterling Mfg. Company 1161
Stevens Manufacturing Co., Inc. 42, 695
Stevens-Arnold, Inc. 36, 387, 691, 1040, 1167
Stiefel Company, Inc., Herman H. 46, 254, 695, 698
Stocker and Yale 591
Stockwell, E. E. 238
Stone & Webster Engineering Corp. 840
Stratex Instrument Company 393, 702
Struthers-Dunn, Inc. 57
Stuart, Victor 340
Sun Radio & Electronics Co. 1168
Superior Electric Company 384, 388, 812
Sylvania Electric Products, Inc. 172, 173, 460, 485, 491, 711, 805, 818, 1034, 1038

T

Taber Instrument Corp. 164, 500, 694
Taco West Corporation 364
Tattall, F. G. 564
Taylor, Jr., J. R. 518
Taylor Instrument Companies 156, 159, 160, 250, 254, 580
Technical Oil Tool Corp. 802
Technology Instrument Corp. 391, 494, 710, 813
Tektronix, Inc. 46, 374, 375
Television Equipment Corp. 1038
Tempil Corporation 42, 948
Tenney Engineering, Inc. 1266
Thermador Electrical Mfg. Co. 1052
Thermal Research & Engrg. Corp. 688
Thermo Electric Mfg. Co. 269, 1272
Thomas, H. W. 1130
Tinius Olsen Testing Machine Company 265, 689, 691
Torsion Balance Company 588
Tour & Co., Inc., Sam 576
Tracerlab, Inc. 168, 938, 939, 1163
Trans-Sonics, Inc. 43, 1036, 1151
Transvision Inc. 267
Triplett Electrical Instrument Co. 166, 818
Tubular Service and Engineering Co. 458

U

Uitti, K. D. 719
Ulanet Company, George 40, 692
Ultra-Violet Products, Inc. 157, 703
U. S. Engineering Co. 269
United Transformer Co. 600
Universal Aviation Corp. 692
Universal Engraving & Colorplate Co., Inc. 831

V

Varo Products Company 496
Valby, Edgar 517
Valtair Corporation 706, 1281
Vanderkamp, J. J. 263
Vanton Equipment Corp. 162
Varo Manufacturing Company 389, 597, 700, 810
Vickers Electric Division 252, 920
Victor Rain Gage Company 52
Viking Tool & Machine Corp. 1149
Viltec Company, F. F. 1251
Vortilla, J. E. 1303

W

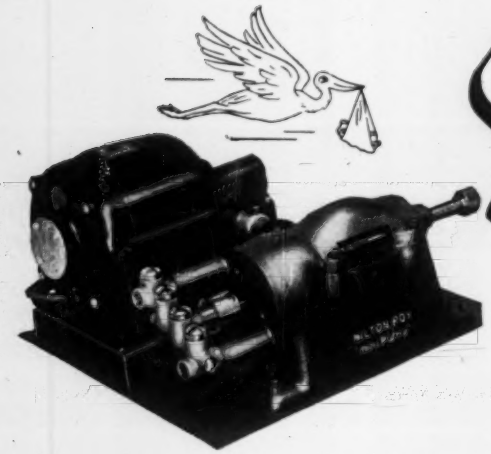
Walker, Kirby 934
Wallace & Tiernan Products, Inc. 916, 920, 1148
Walls, Jr., C. O. 132
Walsef Automatic Timer Corp. 600
Ward Leonard Electric Co. 597, 812
Waterman Engineering Co. 1047
Waterman Products Company 380
Waters, Inc., Robert A. 810, 1030
Weaver, Frank D. 1236
Webber Gage Company 45
Weidler, Paul G. 250, 686
Welch, Melton 1197
Weller Electric Corporation 1048
Weres, R. R. 784
Wescott, Vernon C. 1268
Western Lithograph Company 709
Westinghouse Electric Corp. 43, 55, 158, 162, 269, 572, 589, 694, 800, 1034, 1042
Weston Electrical Instrument Corp. 472, 582, 684, 685, 802, 808, 1028, 1266, 1268, 1272
Wheeler Instruments Company 268, 584, 588, 684, 800, 804
White Co., Inc., David 692
White, Myer P. 1068
Will Corporation 1279
Woodman, Gene 338
Worley, Will J. 241

Y

Yardney Electric Corp. 270, 946

Z

Zenith Optical Laboratory 948
Ziegler, J. G. 66
Zoomar Corporation 808, 944



Announcing the Arrival of "miniPump"

The Newest Milton Roy "Baby"

Mother: —the necessity for precisely metering and pumping liquids in minute quantities.

Father: —the one and only Milton Roy double ball-check design.

Weight: —42 lbs.

Capacity: —3—800 ml/hr

Pressure:—up to 1000 psi.

"miniPump" handles clear liquids in minute quantities at pressures up to 1000 psi. It is a true Controlled Volume Pump, incorporating the exclusive Milton Roy double ball-check liquid end in minified form with a fractional hp motor driver. As with all Milton Roy Pumps "mini" is a positive displacement, precise metering unit.

The liquid end is heat treated type #20 stainless steel, with stainless steel, glass or synthetic sapphire ball-checks, to handle most corrosives. Chamber displacement, or scavenging, is complete over the full range of stroke length adjustment. Capacity is readily varied while operating, from zero to maximum, by a screw and graduated scale adjustment.

"miniPumps" are available in Simplex, Duplex and Multiplex models with motor drive, also as single units powered by 1½" reciprocating air pistons.

If yours is a problem of pumping clear liquids in precisely metered volumes and very small quantities by all means investigate—see what Milton Roy's new "miniPump" can do for you.

MILTON ROY COMPANY

1309 E. MERMAID LANE • PHILADELPHIA 18, PA.

MODEL 350-A

ULTRA-LOW FREQUENCY REJECTION FILTER

variable from 0.02 to 2,000 cps

FEATURING:

ADJUSTABLE CENTER FREQUENCY
ADJUSTABLE BAND WIDTH
BAND REJECTION OR SHARP NULL FILTERING
24 DB/OCTAVE SLOPE
CORNER FREQUENCY PEAKING•LOW INTERNAL NOISE

SPECIFICATIONS:

BAND WIDTH: Sharp null, or continuously variable to maximum width, covering entire range from 0.02 to 2,000 cps.
FREQUENCY RANGE: High and low cut-off frequencies independent, from 0.02 to 2,000 cps.
NULL: Continuous from 0.1 to 500 cps.
SLOPE: 24 db/octave with peaking at cut-off frequencies.
INTERNAL NOISE: Less than 100 microvolts.

DESCRIPTION:

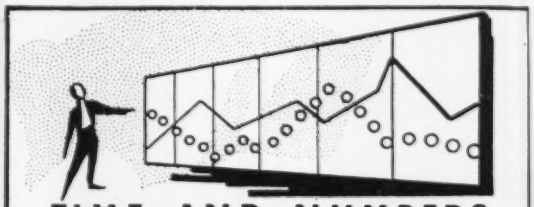
Model 350-A provides either a rejection band in which the gain falls at a rate of 24 db/octave or a sharp single frequency null.

Especially useful for vibration studies, for electromedical research, and for geophysical and seismological instrumentation.

Krohn-Hite quality control, highest quality components, and a one year warranty insure you of a dependable instrument.

KROHN-HITE INSTRUMENT CO.
580 MASSACHUSETTS AVE., CAMBRIDGE 39, MASS., U.S.A.

K-H



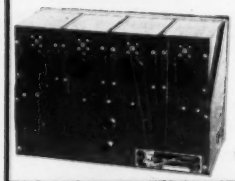
TIME AND NUMBERS

Do you need a permanent record of specific times and numbers that apply to your laboratory or production work? Streeter-Amet has the instrument which will accurately and speedily record either numbers or time or both at the same time on paper tape for easy readability.

The counter operates by any means capable of supplying a switch closure or an electrical impulse. Counts may be indexed by time or number printed alongside the count.

For high speed counting of a predetermined number of completed articles, the Streeter-Amet Predetermined Counter automatically counts and then shuts off or controls associated machinery when the predetermined number is reached. An outstanding time-saver when packing a given number of articles in a carton, measuring lengths of wire or sheets in a bundle.

Tell us your specific counting problem. We know we can help you economically.



Write for illustrated circular SC 13

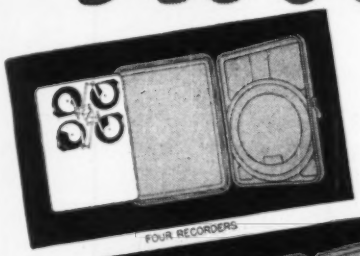
FOUNDED 1888

SCALES-WEIGHT RECORDERS-HI-SPEED COUNTERS

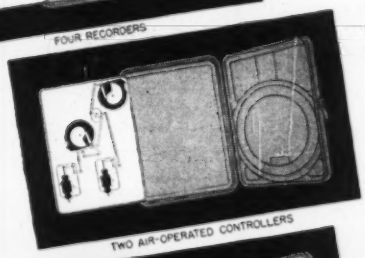
STREETER - AMET COMPANY

4101 N. RAVENSWOOD AVE., CHICAGO 13, ILL.

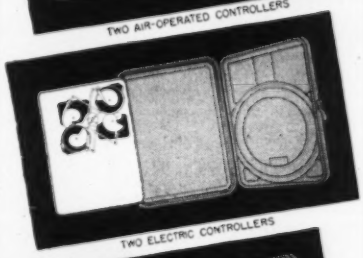
these and 100,000 more



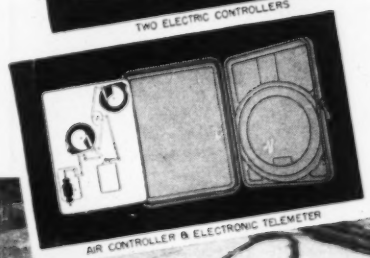
FOUR RECORDERS



TWO AIR-OPERATED CONTROLLERS



TWO ELECTRIC CONTROLLERS



AIR CONTROLLER & ELECTRONIC TELEMETER

FROM 4 CIRCUITS AND 8 BASIC PARTS

What's your control problem? Flow—temperature—level? Are you using solids—liquids—gases?

No matter what you process, four basic circuits and eight basic component parts will give you more than 100,000 different electronic measuring and controlling combinations. That's how Bailey has simplified controls for processing industries.

The four arrangements illustrated show how easily Bailey interchangeable parts can be used. It's no longer necessary to carry a huge stock of replacement parts for emergency control installations. When you standardize on Bailey controls you are always ready to meet changing conditions within your plant.

And with Bailey simplified controls, your maintenance costs will be less. Maintenance men quickly become familiar with Bailey controls and spend less time on maintenance and installation.

To see for yourself how you can profit with Bailey controls, write for a copy of our bulletin No. 17.

BAILEY METER CO.

1041 Ivanhoe Road • Cleveland, Ohio

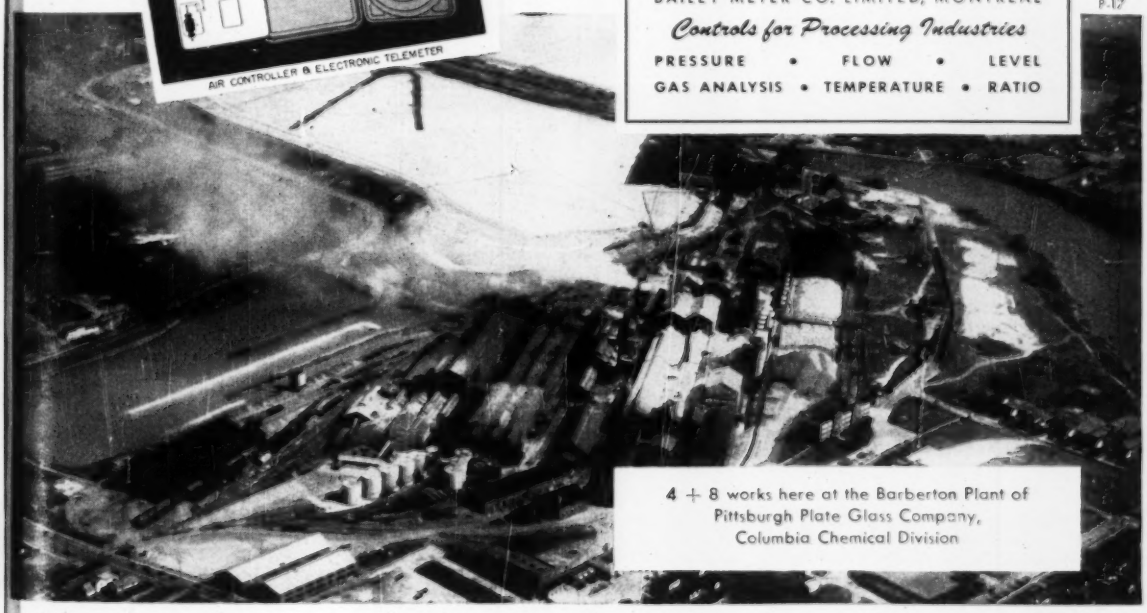
BAILEY METER CO. LIMITED, MONTREAL

Controls for Processing Industries

PRESSURE • FLOW • LEVEL

GAS ANALYSIS • TEMPERATURE • RATIO

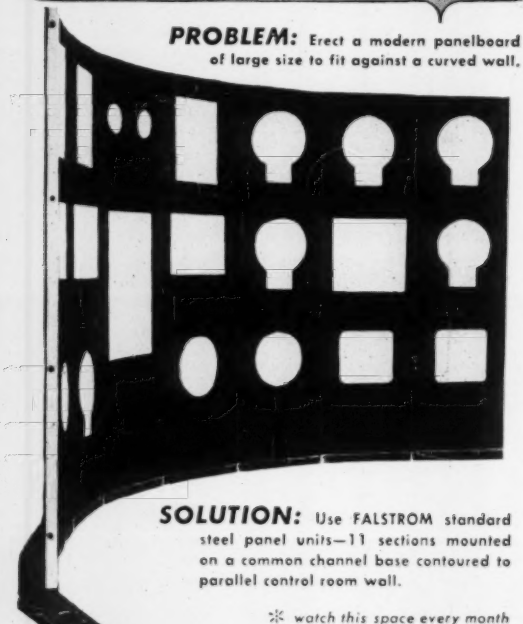
P-17



4 + 8 works here at the Barberton Plant of Pittsburgh Plate Glass Company, Columbia Chemical Division

DOES THIS SOLVE YOUR PANELBOARD PROBLEM?

PROBLEM: Erect a modern panelboard of large size to fit against a curved wall.

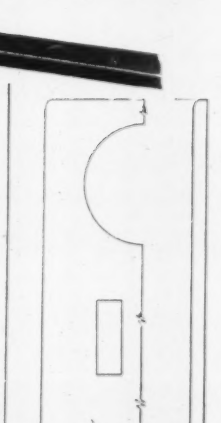


SOLUTION: Use FALSTROM standard steel panel units—11 sections mounted on a common channel base contoured to parallel control room wall.

✻ *watch this space every month for valuable panelboard hints!*

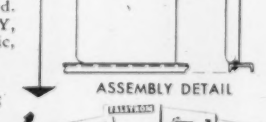
This is an example of Falstrom panelboard design used in many large refineries and public utilities. The use of standard panel units — light in weight, easily carried through doors and stairways or elevators — makes possible quick, easy erection on site. Handsome, strong, neat arrangements of any length or complexity—in straight lines or curves—are as easy to set up as toy building blocks.

Falstrom panel units come to you completely cut out for instruments according to your specifications, with smooth round corners; finished in a rich jet black rubbed finish. All accessories for installation including channel base are included. FALSTROM COMPANY, 40 Falstrom Court, Passaic, New Jersey.



ASSEMBLY DETAIL

WRITE FOR DATA SHEETS on Falstrom Standard Panels and Other Fabricated Steel Products.



FALSTROM
COMPANY • SINCE 1870

DESIGNERS • ENGINEERS • BUILDERS OF CUSTOM STEEL PRODUCTS FOR INDUSTRY

Instruments

Vol. 23 JANUARY 1950 No.

TECHNICAL ARTICLES

Economics of Instrumentation 1
By G. W. McCullough

Purdue's Course in Engineering Instrumentation 5
By George W. Sherman

Concepts of Instrumentation as Taught at The University of Tennessee 9
By Philip Ewald

A New Method of Recording Flight Data 13
By Henry Sostman

SERIAL

Some Application Factors Affecting the Regulation of pH in Industry 17
By Allen L. Chaplin

THE MONTH'S NEW INSTRUMENTS 21

OTHER REGULAR FEATURES

EDITORIAL 1
TECHNICAL SOCIETIES 24
MANUFACTURERS' LITERATURE 25
ADVERTISERS' INDEX 1

JOURNAL of the INSTRUMENT SOCIETY OF AMERICA

Dynamic Accuracy in Temperature Measurement 28
By J. G. Ziegler and N. B. Nichols

Long-range Multi-channel Telemetering System 31
By John T. Mengel

Industrial Radar for Hurricane Tracking 34
By W. F. Gerdes and R. C. Jorgensen

JOURNAL of the SOUTHERN CALIFORNIA METER ASSOCIATION

History of Bellows-actuated Flow Meters 37
By Claude B. Nolte

Index to Vol. 22 (1949) 40

Instruments The Magazine of Measurement and Control is published monthly on the 15th at Pontiac, Illinois. Editorial, Subscription and Advertising Offices are at The Instruments Publishing Company, 921 Ridge Avenue, Pittsburgh 12, Pa.

Richard Rimbach, *Publisher* — M. F. Behar, *Editor*

James F. Emge, *Assistant to the Editor* (new literature, etc.)

DISTRICT OFFICERS AND MANAGERS

MEMBER ABC Audit Bureau of Circulations

James Condon, 36 Myrtle St., *Boston* 14, Mass. (Lafayette 3-0829). Richard J. Rimbach, Jr., Room 358, 551 Fifth Ave., *New York* 17, N. Y. (Murray Hill 2-0821). William J. Gallagher, 660 Park Lane, *Philadelphia* 44, Pa. (Victor 4-2894). Harold W. Haskett, 742 Elberon Ave., *Cincinnati* 5, O. (Grandview 4323); Room 615, 360 N. Michigan Ave., *Chicago* 1, Ill. (Andover 3-4299). James R. Wright, 411 North Tenth St., *St. Louis* 1, Mo. (Chestnut 1965). M. D. Purdy, 2721 N. Marengo Ave., *Altadena*, Calif. (Sycamore 7-2894). C. F. Goldcamp, 921 Ridge Ave., *Pittsburgh* 12, Pa. (Fax 1-0161).

SUBSCRIPTION RATES

	One Year	*Two Years*	*Three Years*
United States, U. S. Possessions and Canada	$3.00	$5.00	$6.00
Latin America and Australia	4.00	6.00	8.00
All other countries except those noted below	5.00	8.00	10.00

For the present, subscriptions not accepted from Austria, Bulgaria, China, Czechoslovakia, Germany, Hungary, Poland, Rumania, Russia and Yugoslavia.

Payments from outside the U. S. A. must be in the form of an International Money Order or check on a U. S. bank.

Position and company connection as well as products manufactured must be indicated on all subscription orders.

Copyright 1950 by The Instruments Publishing Company, Inc.

Office of publication, 1600 North Main St., Pontiac, Illinois. Executive and Editorial Office, 921 Ridge Avenue, Pittsburgh 12, Pa.

Entered, as second class matter, October 14, 1949, at the post office at Pontiac, Illinois, under the act of March 3, 1879.

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Owing to the importance of temperature measurement and control in all industries, we gladly "yield the floor" this month to the Proficient Priests of Precision at the NBS.

National Bureau of Standards
U. S. Department of Commerce
Washington 25, D. C.

Technical Report 1414

REVISION OF THERMOCOUPLE TABLES

An extensive project is now under way at the National Bureau of Standards for revision of all the common thermocouple tables in order to take into account the recent changes in electrical units and in the International Temperature Scale. Present plans call for the publication during 1950 of eight tables giving the temperature-emf relations for platinum-platinum rhodium, chromel-alumel, and copper-constantan thermocouples.

The temperature-emf tables for thermocouples previously issued by the Bureau have been widely used in science and industry, not only to convert thermocouple voltages into the equivalent measured temperatures but also in the preparation of purchase specifications for thermocouple wire and in defining the relation between impressed emf and scale reading for pyrometers which indicate temperature directly. Recently, however, in accordance with international agreement, the Bureau adopted the absolute electrical units and began using the definitions of the new International Temperature Scale of 1948 both in its own research program and in calibrating instruments for other laboratories and industries. Revision of the thermocouple tables was then advisable in order to make them consistent with former usage.

In the preparation of the tables, emphasis is being placed on convenience for use. Thus, the explanatory text will be short, the numerals will be as large as practical, and the layout of pages and headings will be arranged to facilitate interpolation. The argument will be presented at one-tenth the interval given in the original tables. Inverse tables, formerly lacking, will also be included. Each table, together with its inverse, will be issued as an NBS Miscellaneous Publication and, when announced, will be available from the Superintendent of Documents, U. S. Government Printing Office. The following tables are expected to become available during 1950:

1. Reference table for platinum vs platinum-10% rhodium thermocouples: emf at intervals of 10 microvolts vs degrees C; temperature at intervals of one degree C vs microvolts.

2. Reference table for platinum vs platinum-10% rhodium thermocouples; emf at intervals of 10 microvolts vs degrees F; temperature at intervals of one degree F vs microvolts.

3. Reference table for platinum vs platinum-13% rhodium thermocouples; emf at intervals of 10 microvolts vs degrees C; temperature at intervals of one degree C vs microvolts.

4. Reference table for platinum vs platinum-13% rhodium thermocouples; emf at intervals of 10 microvolts vs degrees F; temperature at intervals of one degree F vs microvolts.

5. Reference table for chromel-alumel thermocouples; emf at intervals of 0.1 millivolt vs degrees C; temperature at intervals of one degree C vs millivolts.

6. Reference table for chromel-alumel thermocouples; emf at intervals of 0.1 millivolt vs degrees F; temperature at intervals of one degree F vs millivolts.

7. Reference table for copper-constantan thermocouples; emf at intervals of 0.1 millivolt vs degrees C; temperature at intervals of one degree C vs millivolts.

8. Reference table for copper-constantan thermocouples; emf at intervals of 0.1 millivolt vs degrees F; temperature at intervals of one degree F vs millivolts.

The NBS tables for iron-constantan thermocouples will not be revised until completion of an investigation into the properties of some commercially available iron-constantan thermocouples, which is now being carried out by the Bureau in cooperation with the Scientific Apparatus Makers of America.

A limited number of rough-draft advance copies of the first two publications has been prepared to meet interim demand where the need is great. Others will become available in the order listed. Inquiries and suggestions regarding the tables should be addressed to Dr. Robert J. Corruccini, Pyrometry Laboratory, National Bureau of Standards, Washington 25, D. C.

Economics *of* Instrumentation

By G. W. McCULLOUGH, Vice President and General Manager, Phillips Chemical Company, Bartlesville, Oklahoma

Introduction

FOR many years the factors required to obtain the best in performance at minimum cost from an automatic plant process control system have been of the deepest interest to the Management of the Phillips Petroleum Company. This interest in plant control was born during the earliest days of the Petroleum and Gas Industry, when the first natural gasoline plants of simple design, operating to produce a fuel of limited specification, utilized automatic controls as the most economical means to achieve the maximum production.

As the industry continued to develop, and new uses were found for the varied components of natural gas and gasoline, the instruments used for the automatic control of process flows were progressively improved. With the advent of the Chemical Plants employing petroleum products and feed stocks, the proper economical use of instruments to obtain quality specification product through continuous flow demanded the immediate development of many types of new instruments.

Instruments are now in use that handle precise and complicated cycling schedules that are too rapid, delicate or complex to be entrusted to human hands, thus making possible mass production of high-purity products that were only laboratory dreams a few years ago. With proper controls, duplication of any operation is possible, and the exacting standards of specifications of a product can be constantly maintained.

Too, World War II originated many new types of instruments and this war was won by the United States and its allies in large part because this nation was able to out-do its enemies in producing the technical instruments needed, and in training personnel in great numbers to operate them. The production of the atomic bomb was made possible because the talents of all industries were pooled, and the wonders performed at Oak Ridge and its sister plants enabled the quicker subjugation of Japan through the reduction of Hiroshima and Nagasaki. All America can be thankful for the savings in lives and money thus obtained.

These complex instruments have not been used to any great degree in present-day plant operation, but the plants of the future built as complete new units will call for the adaptation of some of these items.

From the standpoint of production, efficiency and investment, the writer has carefully surveyed the subject of plant instrumentation based upon the operation of several types of plants. For the consideration of members of the industry, many of the points studied during these surveys, applicable to general use, are presented herewith.

Factors Affecting Cost

In an approach to an analysis of the requirements for good measurement and control, several items must be considered to assure that the plant process flows will be properly provided with instrumentation consistent with the general purpose of the plant. Competition in the petroleum and chemical fields is becoming keener each year, and the future will see succeed those companies which recognize and make use of the advanced instruments available to the industry.

Some of these factors are routine and, while involving matters of the greatest importance in the operation of the measurement and control equipment, are of basic knowledge of a group such as is present here today. It has been decided to discuss these interesting factors but briefly in order to favor a discussion of the instruments which will be possible for the operation of the plants which will be developed in the future.

Basic Instruments. In broad terms, these instruments may be classified as those used to effect quality control differing, in the main, from the routine type used for temperature, pressure, level and flow control in that they are located in the process closer to the product stream, and function to reset the routine type instrument for a finer cut. This close control is not necessary in the standard gasoline plant, since its product is usually delivered to a central point for fractionation and purification. However, in a special product plant manufacturing individual hydrocarbon cuts, and in special product plants, i.e., producing butadiene to a high standard of purity, extremely close control is necessary to assure that the product meets specification. This is true also with regard to chemical product plants manufacturing ammonia, ammonium sulphate, ammonium nitrate, nitric acid, etc.

Safe Practice. The use of the more complicated instruments sometimes requires that an interlocking sequence of operation be used so that flows cannot be mixed accidentally with an explosive hazard created. This concern for safe practice has, of course, added to the cost of instrumentation of petroleum-chemical product plants.

Cost Center Records. Another item that must be considered as a factor affecting the instrument percentage cost figure is the provision for proper records showing cost and production figures. In most petroleum-chemical plants the cost control must be carefully watched, since most process streams involve costly ingredients.

Project Permanency. Too often in the past, plants have been built on the assumption that they would be short-lived; however, as the continued use developed, revamping and adding instrumentation has increased the cost percentage above that necessary had it been possible to base the cost on the actual period of operation.

Cascade Type Controls. The use of cascade type control installations, whereby an over-riding controller is used to reset an instrument to position a motor valve controlling a process variable, eliminates unusual or lengthy process time lags. Instruments used in this manner provide a means of obtaining precision quality and are adaptable to use with computer type panels when such are more fully developed.

Typical Process Use

Gasoline Plant. The instrumentation required for a natural gasoline plant is even today of a simple nature. The principal changes have been in the use of improved types of instruments for standard variable control. Transmission of flow differential, pressure and temperature has permitted the centralized location of equipment and has eliminated much of the difficulties encountered in winter operation.

Reducing the number of service calls and process interruptions has saved thousands of dollars. Too, the use of this type instrumentation has afforded a stepping stone useful in the transition steps necessary to the training of personnel capable of handling the more complex instruments required in other type plants.

Table 1 includes figure for an early-day type plant using the simpler type of direct-connected instrument. The cost percentage figure is low, since the type of instrument was based on that needed for the manufacture of a product to less stringent specifications than those demanded of today's natural gasoline plant.

Table 2 shows the investment necessary to a modern natural gasoline plant. Using a leaner natural gas as feed presents more difficult extraction problems and, operating to maximum efficiency on a year round basis calls for winter-proof construction. The dollar value of the product is not too different from that of the early gasoline plant but the operating conditions have changed, requiring better instrumentation to make possible the economical processing of the lean gases.

Fractionation of Hydrocarbon Feeds. In the fractiona

*Presented at Short Course on "Instrumentation for the Process Industries," Texas A & M College, Oct. 12-14-1949.

	Table 1 Early Day Gaso. Plant	Table 2 Modern Gaso. Plant	Table 3 Refining Crude Unit	Table 4 Spec. Product Butadiene
Total Plant Investment	$1,600,000	$2,500,000	$2,250,000	$38,000,000
Instruments Installed	$ 25,000	$ 90,000	$ 125,000	$ 2,200,000
Percentage	1.5 percent	3.6 percent	5.5 percent	5.8 percent
Selling Price	5 cents/gal.	5 cents/gal.	7 cents/gal.	12 cents/pound
	Table 5 Chemical Plant Anhydrous Ammonia	Table 6 Chemical Plant Nitric Acid	Table 7 Chemical Plant Ammonium Nitrate	Table 8 Chemical Plant Ammonia Sulphate
Total Plant Investment	$23,000,000	$1,500,000	$3,000,000	$1,800,000
Instruments Installed	$ 690,000	$ 30,000	$ 60,000	$ 40,000
Percentage	3 percent	2 percent	2 percent	2.2 percent
Selling Price	3.75 cents/pound	5.5 cents/pound	3 cents/pound	2.52 cents/pound

tion of hydrocarbons to a desired kettle and overhead product, the vapor pressure at any given tray location within the vessel is an indication of the purity of the product at that point. A recent development has brought forth a differential pressure controller utilizing a bulb filled with the product desired at that point. Installed in the vapor space above the tray in which a quality product is desired, this controller functions so that, as the pressure at that point of application varies, the product in the vessel operates one side of a flexible diaphragm opposed by the vapor pressure within the sealed tube of the instrument representing the product desired. The movement of the diaphragm causes an actuating air pressure to vary the ratio of reflux to column feed to maintain proper quality overhead and kettle product accomplished as resetting a flow controller on the reflux line.

Table 3 shows the instrumentation cost for a refining plant. Many of the comments for the modern gasoline plant apply to the refinery except that a higher priced product permits more complete instrumentation based upon more precise quality products and year round operation.

Butadiene and Butane. Data from government-owned and-built plants have been reviewed and the use of the spectrophotometer using infrared ray phenomena to analyze the constituents of a flow stream has been developed to the extent that it is now suitable for control applications. This type instrument has been used for several years as an indicating or recording analyzer but only recently has its control possibilities been utilized. The greatest handicap to the earlier use of this instrument was the necessity to take time to develop personnel capable of handling the equipment. Also, some of the mechanical difficulties involved, such as those encountered obtaining a clean flow stream, clean sample piping, etc., had to be overcome. This instrument, used to determine the purity of a butadiene flow stream, has greatly increased the efficiency of production. This has been possible through the anticipatory information obtained quickly so that necessary process variables could be changed before the column was upset beyond quick adjustment.

The spectrophotometer has possibilities also in the analysis of a flow stream containing butane used as feed to a butadiene manufacturing plant. The quality of the butane stream is maintained through the proper adjustment of process variables. The use of this type instrument will be greatly expanded in the next few years.

Since the production of butadiene in the plant built and operated by Phillips Petroleum Company for the United States Government was based upon the two-step catalytic dehydrogenation of butane, cyclic operation of the process control gate valves was necessary. Owing to the multiplicity of valves and the short time periods involved, human manipulation of this equipment could not be relied upon for the repeated operation of these units to a predetermined cycle.

The timing program was further complicated since purging of the flow lines was required before the hydrocarbon stream could be readmitted to the lines used jointly for regeneration and feed. An electrically-wired interlocking system was employed to assure one correct valve sequence to avoid an explosion hazard which would be presented should hydrocarbon and the oxygen containing regeneration gas streams be mixed.

An electric timer was used to send an electrical impulse to the control valve with the cycle temperature program developed by means of a metal circular chart cut to a desired contour. These two instruments were synchronized electrically so that the proper valves were opened or closed during optimum temperature conditions.

The instrumentation necessary to the two catalytic dehydrogenation steps effected quality control, simplifying the fractionation steps following each catalytic unit. Selective absorption and purification with furfural as the medium was employed to separate the butenes for feed to the second catalytic step and to secure butadiene as the final product after the second dehydrogenation cycle. Close control of the process variable was needed in these units to avoid unnecessary loss of absorbent and to avoid the production of butadiene which would not meet the exceptionally high standard of purity demanded for use as feed to the copolymer plant producing latex used in the production of synthetic rubber.

Table 4 shows the cost comparison for a special product plant. Here it will be seen that the price of the product has greatly increased. The problems of precise control and year round operation permit that the complex instrumentation necessary to achieve quality control may be a relatively high percentage figure.

Nitrogenous Products Plants

Anhydrous Ammonia. The manufacture of anhydrous ammonia has presented an opportunity for the use of many types of quality control instruments with much yet to be gained as further knowledge is obtained. Phillips Chemical Company's entry into the production of ammonia has increased the use of automatic control to most of the process flow. The original plant design, erected during the war period 1942-3, was based on World War I chemical plant practices with many flow streams operated manually. It has been necessary to educate the present operators in the use of this new type equipment and to allay their fears regarding the reliability of its operation. To accomplish this necessitated the strengthening of the instrument section personnel and providing facilities for 24-hour service.

New instrument and control applications which have been completed and are under study are numerous. In the synthesis step, liquid level control of the product from the cold exchangers has been possible through the development of a displacement type level controller suitable for the high pressure necessary to the application. The use of instruments at this point has released personnel to supervise other critical operations within the unit and has provided a more constant flow through the plant.

Another quality control instrument is a methane analyzer considered for use on the nitrogen-hydrogen stream from the converter. Study of this application has not been completed and is mentioned at this time only to indicate a possible location or further automatic control of a plant process step.

In the gas reforming step, consideration has been given

to using a hydrogen analyzer as a quality controller. As in the above-mentioned application, study is not complete at the moment as to the exact mechanical adaptations necessary; however, it too, is mentioned to afford an insight into the wealth of applications yet to be explored where automatic control of process variables can be made economically to provide more precise quality product.

Table 5 contains the most comparison for a plant producing anhydrous ammonia. In this type plant the percentage cost figure is somewhat low because of the use of alloys for many of the lines and the extreme operating pressures needed in the synthesis step of the process.

Nitric Acid. In the manufacture of nitric acid, the oxidation of ammonia in the presence of suitable catalyst at elevated temperatures is accomplished with the catalyst gauze temperature controlled by permitting the by-pass of a volume of cool air. However, in this process the presence of oxygen in the effluent gas stream from the nitric acid absorber is a critical indication of the efficiency of the total process, and is used to reset the temperature control instrument maintaining temperature preceding the catalyst chamber. In this manner process lag through the entire system is cut to a minimum with the quality of the feed to the absorption column maintained to a precise quality.

In this same process another application for quality control is the use of a conductivity control unit calibrated in terms of percentage concentration nitric acid. This unit is connected to the outlet of the absorption column with its control established through a motor valve located on the water to the tower. This application is a direct control unit aimed to maintain a specific quality product.

Table 6 shows the cost figures for a plant manufacturing nitric acid using ammonia and oxygen reacting in the presence of a catalyst. The total investment of such a plant is not great, but the cost percentage figure is low because of the use of special alloys in the vessels and lines, making the investment out of the usual proportion for controlled variables to major equipment.

Ammonium Nitrate. In the manufacture of ammonium nitrate, the mixing of ammonia and nitric acid to the proper proportion is the key operation of the process, and the pH indication of the condensate from the neutralizer is a critical criterion of the efficiency of proper mixture. Ratio flow controllers are used on the ammonia and acid streams preset to a definite ratio and account for major control of the two flows. The pH value determined from a sample stream located in the vapor or condensate stream from the neutralizer is used by means of a pH controller to reset the ratio controller. This allows the pH value to be adjusted to that desired for a more perfect ratio and avoids much of the time lag which would otherwise be introduced into the system.

Table 7 shows a typical chemical plant manufacturing ammonium nitrate. This plant shows the cost percentage figure for instrumentation rather low. This is because the major equipment, although based upon much smaller process flows, requires many of the vessels and other equipment to be of special alloys which greatly increase the cost of total investment to that for measurement and control.

This table gives relative figures for a chemical plant manufacturing ammonia. In this plant Phillips has made changes from many chemical industry methods of operation to those based upon petroleum industry practices. While quality control application equipment is used, this plant represents compromise instrumentation.

Ammonium Sulphate. A plant in which sulphuric acid and gaseous ammonia are combined to produce ammonium sulphate was recently completed. This plant based upon continuous process flow operation has provided applications for automatic control not encountered in some of the earlier plants producing ammonium sulphate.

A pH recorder is used to afford a means of checking the efficiency of the chemical reaction of the sulphuric acid and ammoina gas and as a guide to the control of the product to the desired quality.

A ratio controller is used to provide the correct amount of acid dependent on the base flow of ammonia gas. Through this means small fluctuations in ammonia gas flows are adjusted automatically by the increase or reduction in the amount of acid admitted to the ammonia stream. This instrument installation has reduced the effect of the human element present when these two flows are manually set to a fixed ratio.

Temperature controllers make continuous flow through automatic dryers possible, eliminating the batch plant type of operation which was often used in the past. Automatic weighing and bagging machines further facilitate the handling of the product to storage.

Table 8 presents cost figures for comparison with other chemical product plants.

Computers Used with Quality Controllers. All of the control applications and the instruments used to achieve an end product are those used to maintain quality and are of the type which will be suitable for adaptation to a computer type panel.

Using a computer in conjunction with suitable instruments, it will be possible to turn a dial to a quality desired, and the computer will then function to reset a ratio control of feed to reflux for a column, or control the water flow over a tower to maintain a proper concentration of an acid, etc. Though at the present moment these computer instruments are used in many phases of aircraft navigation, the instrument companies have fabricated experimental models using principles as indicated herein for process control and it is possible that units will be available to the industry for special application in the near future.

A plant built to operate using some modification of the Fischer-Tropsch process to manufacture gasoline using methane as the primary hydrocarbon, will require a cost percentage figure in the neighborhood of ten percent. This will be due to the exacting nature of the process not only for the production of the oxygen, but in the reforming and synthesis steps as well.

Perhaps better instrumentation will help to make this process financially attractive and in some part permit its economical construction.

Future and Personnel

A main factor upon which the use of the more complex instrumentation is based involves the training and developing of personnel qualified to design, operate and maintain this complex instrumentation. In the early days of the petroleum industry the instrument men were chosen from personnel who had shown an ability to repair things, hay binders or automobiles. Today's specialized equipment is a challenge to the technical graduation.

The colleges of Engineering at several schools have now included in their curricula, courses on instrumentation which provide a means of training men during their school years. This inclines these men further toward an interest in this work and, from this group, management can select men who have at least indicated a desire to follow this phase of engineering.

Through this step educational groups have acknowledged the need for basic training in instrument design and application, and are attempting to do their part in the advancement of measurement and control.

Too, the recent establishment of the Instrument Society of America, organized to function along the lines of other bodies such as the American Society of Petroleum Geologists, American Society of Mechanical Engineers, etc., has done much to alert men responsible for the economical production of special products to an understanding of the important place automatic control instruments occupy in present-day plant operation.

In order for a technical graduate to be interested in following this phase of engineering has meant that the management of the various companies in the Petroleum-Chemical Industries has had to become measurement and control conscious. Management has had to base its concept of personnel placement in an organization chart in a strong enough position, so that a technical graduate could be satisfied with the opportunities for salary and progress, using measurement and control as his medium. Many of the larger companies, recognizing that it will be through the further use of the technical graduate that added advantages from better instrumentation will be gained, have placed graduates in the company engineering and operating departments to serve as key personnel.

Purdue's Course *in* Engineering Instrumentation

In the School *of* Chemical *and* Metallurgical Engineering

By GEORGE W. SHERMAN, Associate Professor of Chemical Engineering,
Purdue University, Lafayette, Indiana.

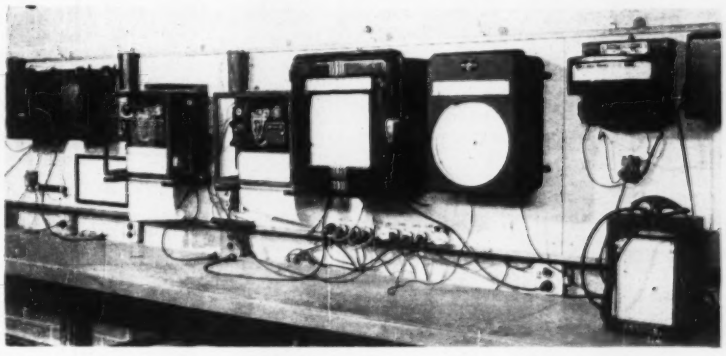
IN response to the rapid increase in instrumentation in all types of processing, many schools have included this subject in their engineering curricula.

There is an urgent demand by industry that the engineering student have training in the instrumentation field. Therefore, it seems that more attention should be given to this often-neglected field.

Some have separate courses while others have the instruction included in other courses. At Purdue University we have a separate course administered in the School of Chemical Engineering.

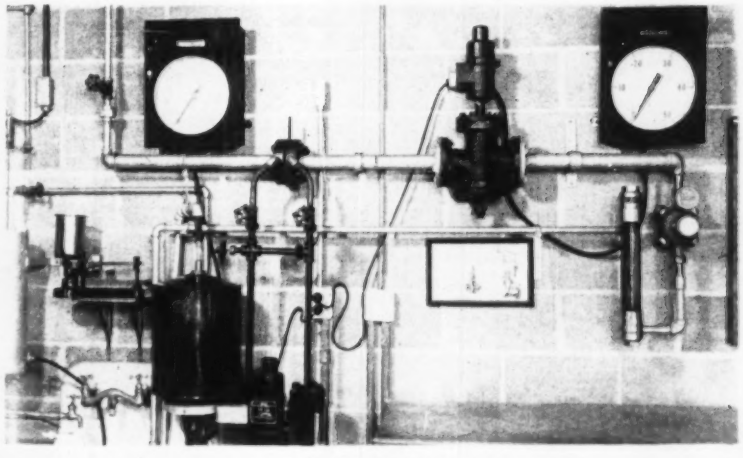
A separate course seemed more desirable for two reasons. First, when administered as a separate course the student has his attention focused on the material in a much more forceful manner than if it is attached bit by bit to other courses where he may be led to think of it only as a "filler." Secondly, it is much more desirable to have one member of the teaching staff, who is trained in this particular field, administer the course — because he can give much of his time and energy to the subject rather than to attempt to have the entire staff teach the subject as a side line. The latter method might be, in many cases, more of an annoyance than a matter of interest to the staff member, who has his main interest in another subject.

The subject matter of instrumentation is closely related to many other courses and, when administered late in the curriculum, serves as a means of review and as a correlating course. Such a course, properly taught, will help the students to comprehend the fact that each integral part of the plant is an important link in an over-all project, the aim of which is to produce some product in the most economical way possible. Such a course cannot help but enlarge the student's view of process operation.



Recorders and Controllers.

The course in Engineering Instrumentation at Purdue University was started in the fall of 1913 under the name of "Pyrometry" at the request of Professor H. C. Peffer who was at that time the Head of the School of Chemical Engineering. The course at that time was confined to the measurement and control of temperature. Later, as automatic control methods were developed for other conditions and properties, the course was expanded to include flow, flow ratio, pressure, level, viscosity, pH, smoke density, humidity, specific gravity, and CO_2 measurement and control. About 1935, observing that M. F. Behar had been using his term "Instrumentation" in his serials, we called it by that name.



Liquid Flow Meters

At the beginning of the course the student is made acquainted with the basic principles of measurement. This part of the course includes a discussion of accuracy and sensitivity and their effect on the end product of the control. Errors due to the measuring instruments are considered fully, including the changes in the condition being measured due to the measuring element, and those errors due to the various lags, etc.

In the measurement and control of temperature the student studies thermoelectric, resistance, pressure, radiation, optical, and photoelectric methods. This work includes the consideration of various measuring elements as best applied to the measurement of temperature under various conditions. Studies of the measuring instruments such as the millivoltmeter and potentiometer, together with the advantages and disadvantages of the various types, are included.

Consideration is given to the problem of thermometer wells and protecting tubes, including lag problems, corrosion etc.

In the measurement and control of flow and flow ratio, the Venturi, the orifice plate, and Pitot tube, the rotameter, current type meters and volumetric meters are discussed.

For the other conditions and properties, such as level, pressure, humidity, viscosity, smoke density, and pH, there is a similar coverage.

In the problems of control, various types are studied, starting with simple on-off types and progressing through proportioning, proportioning with reset, and on to the more recent types. The operating characteristics and proper application of the various types are discussed.

In the study of control problems, comparison is made between self-operated and servo-operated devices. Telemetering and signal transmission is fully

covered as is the relative advantages of electric, pneumatic, and hydraulic systems for relay and positioning devices.

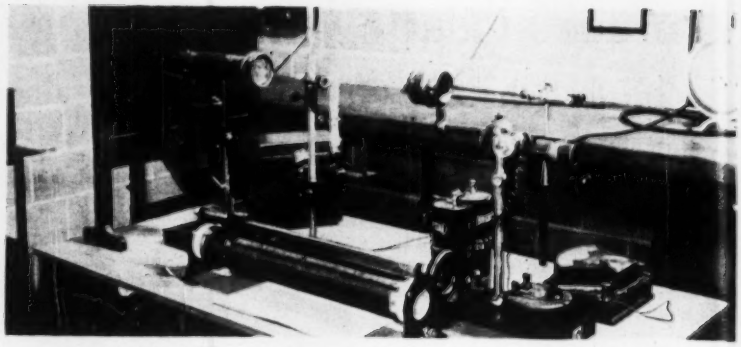
EXPERIMENTS FOR LABORATORY

George W. Sherman

1. Study of resistance thermometer.
2. Freezing point method of thermocouple calibration.
3. Calibration of thermocouples by comparison.
4. Installation of thermoelectric pyrometers.
5. Study of lags in measurement.
6. Study of automatic control mechanisms, on-off.
7. Study of electric proportioning controls, reset, rate.
8. Study of pneumatic proportioning controls, reset, rate.
9. Study of radiation pyrometers.
10. Study of optical pyrometers.
11. Measurement of emissivity.
12. Flame temperature measurement, line reversal.
13. Study of gas flow meters.
14. Study of liquid flow meters.
15. Level and density measurements and control.

ITEMS TREATED IN LECTURES FIRST MONTH

1. Direct and Inferential method of measurement
2. Accuracy
3. Sensitivity
4. Instrument Change
5. Seebeck Effect
6. Peltier Effect
7. Thompson Effect
8. Qualities of Elements
9. Thermoelectric Power
10. Homogeneity, Parasitic Currents
11. Common Types of Couples
12. Iron-Constantan Couple
13. Copper-Constantan Couple
14. Chromel-Alumel Couple
15. Plat — Pt-Rh. Couple
16. Reference Junctions, Wells
17. Placement of Couples
18. Extension Leads
19. Reference Junction Corrections
20. Thermoelectric Installations
21. Protecting Tubes
22. Lag Coefficient
23. Thermoelectric Indicators
24. Millivoltmeters
25. MV. Action
26. Pyromillivoltmeters
27. Potentiometers
28. Pot. General Principle
29. Pot. Scale Sensitivity
30. Pot. Scale Shift
31. Pot. Ref. Jct. Correction
32. Pot. Advan. and Disad.
33. Resistance Pyrometry
34. Basic Principles of Res. Therm.
35. R.T. Coil Material
36. Wire Size for R.T.
37. Mounts for Coils
38. Protecting Tubes for R.T.
39. Measurement Bridge
40. Dummy Leads
41. Direct Reading Bridge
42. Placement of R.T.
43. General Use of R.T.
44. Range
45. Accuracy
46. Test



Flame Temperature Measurement by the Line Reversal Method.

ITEMS TREATED IN LECTURES SECOND MONTH

1. Thermal Radiation
2. Nature of Thermal Radiation
3. Range of Thermal Radiation
4. Radiation Laws
5. Blackbody, Gray Body
6. Total Emissivity
7. Absorptivity
8. Artificial Blackbody
9. Theory of Radiation Pyr.
10. Stefan Boltzman Equation
11. Radiation Temperature
12. Three Parts of Rad. Pyr.
13. Precautions for Rad. Pyr.
14. Use of Rad. Pyr.
15. Theory of Optical Pyr.
16. Wien's Law
17. Applied Scheme of Opt. Pyr.
18. Morse Thermogage
19. L & N Opt. Pyr.
20. F & F Opt. Pyr.
21. Pyro Opt. Pyr.
22. Brightness Temperature
23. Spectral Emissivity
24. Means of Emissivity
25. Conversion S to T
26. Extension of Range
27. Electric Eye Pyr.
28. Secondary Standards
29. Line Reversal Method
30. Balance Methods of Pressure Meas.
31. Limp Diaphragm
32. Bell Types for Pressure
33. Piston Types for Pressure
34. Bourdon Gages
35. Helix, spiral gages
36. Diaphragm, Bellows Gages
37. Piezoelectric Gages
38. Conductivity Gages
39. Theory of Pres. Therm.
40. Pressure Therm Bulbs
41. Pressure Therm Capillary
42. Gas Properties
43. Ambient Temp. Correction
44. Properties of Liquids
45. Liquid Filled Bulb Position
46. Vapor Type Liq. Properties
47. Vapor Type Bulb Position
48. Vapor Type Amt. of Liq.
49. Rel. Adv. of Pres. Therm Types
50. Uses

Test

ITEMS TREATED IN LECTURES THIRD MONTH

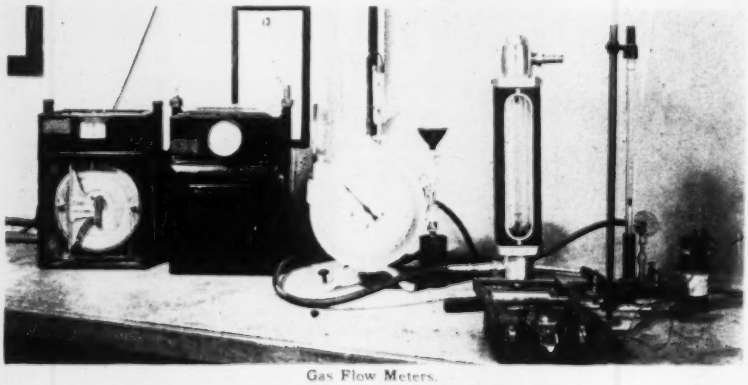
1. Venturi Meters
2. Flow Nozzles
3. Orifice Plates
4. Pressure Taps
5. Orifice Plate Construction
6. U Tubes and Bellows
7. Flow Meter, Steam
8. Flow Meter, Gas
9. Flow Meter, Liquids
10. Pitot Tubes
11. Flow Meter Cycling
12. Blow-out Cheeks
13. Motion Transmission
14. Gyroscopic Flow Meter
15. Rotameters
16. Area Piston Type
17. Anemometers
18. Volumetric Piston
19. Volumetric Bucket
20. Volumetric Bellows
21. Volumetric Slide Vane
22. Current Types
23. Level Measurement
24. Bubble Type for Level
25. Bubble Type for Density
26. Telemetering
27. Advantages of Various Types
28. Electric Telemetering
29. Current Telemetering
30. Inductive Telemetering
31. Voltage Variation
32. Frequency Variation
33. A-c. Bridge Tele.
34. Selsyn Motor
35. Advantages of Automatic Control
36. Process Lags
37. Instrument Lags
38. Control Mechanism Lags
39. Dead Time

Test

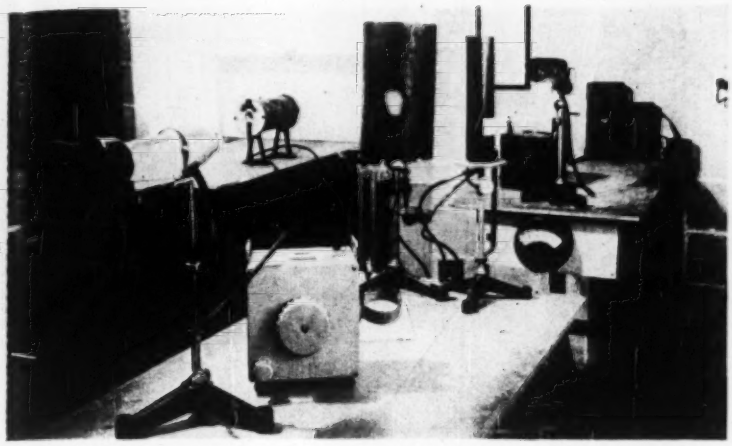
ITEMS TREATED IN LECTURES FOURTH MONTH

1. On-off Control
2. Proportioning Control
3. Proportioning with Reset
4. Floating Control
5. Rangeability of Valves
6. Valve Port Design
7. Balanced Plug
8. Valve Operation
9. Electric Throttlers
10. Self vs. Servo
11. Self-operated Temp.
12. Self-operated Pressure
13. Pressure Boosters
14. Self-operated Level
15. Electric Relays
16. Magnetic Servo
17. Pneumatic Servo
18. Flapper Valves
19. Hydraulic Positioners
20. Flow Control
21. Control Valve Placement
22. Flow Ratio Control
23. Liquid Level Control
24. Feed Water Control
25. CO_2 Control
26. Smoke Control
27. pH
28. Humidity
29. Viscosity
30. Specific Gravity Control
31. Proportional Control Devices

Test



Gas Flow Meters.



Optical Pyrometers and Measurement of Emissivity.

Some time is spent on the proper design of the plant in its relation to its future control. Attention is also given to the problem of providing the proper amount of [illegible]ation for a maximum financial return on the process.

The laboratory is equipped with many types of measuring and control devices. Included in this apparatus are six temperature controllers of various make and several temperature recorders. Seven flow meters of various types are provided for student experiments. Density and level measuring apparatus is also available in the student laboratory. There is also considerable equipment for calibration.

Fourteen electric furnaces and ovens in the laboratory may be used for calibration and for study of control problems. The laboratory is well supplied with portable measuring instruments such as millivoltmeters and potentiometers.

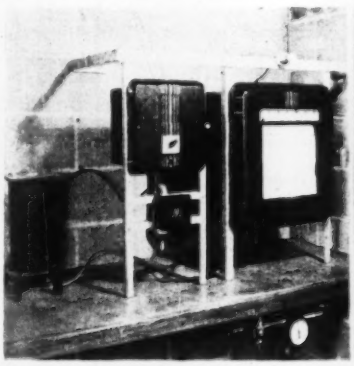
The course consists of two lectures and one three-hour laboratory period per week for one seventeen-week semester. Supplementary to the lectures, "Industrial Instruments for Measurement and Control" by Rhodes is used as a textbook. In addition to the text, "Industrial Process Control" by Eckman and "Automatic Control Engineering" by Smith are available to the student for further study. Bulletins of the Bureau of Standards and various trade bulletins are also provided for reference.

The aim of the course is not to train technicians, but rather to train engineers to the end that they will have the fundamental knowledge necessary to understand the problems of engineering instrumentation. Time is spent on special mechanisms only to acquaint the student with the basic principles of the measurement and control of the particular condition or property.

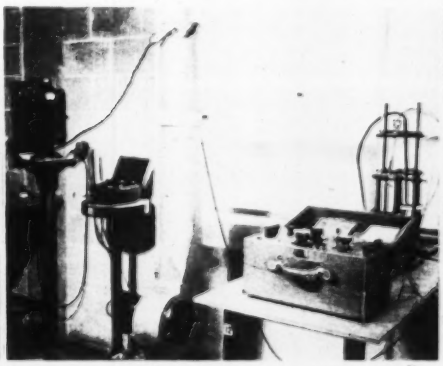
The content of the course is directed to supplying the student with that knowledge which will enable him to choose the proper instruments for the job at hand, to superintend the correct installation of these instruments, to superintend the operation and maintenance, and to determine the proper balance of instrumentation for a maximum financial return on the investment.

In view of the present trend toward complete automatic control of processes, the student is made aware of such trends to the end that he may be prepared to orient his thinking to the rapidly developing changes in design of process devices and their instrumentation.

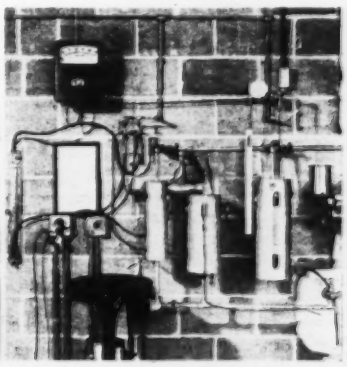
This course is required of all seniors in Chemical and Metallurgical Engineering and is offered as an elective for all other engineering students.



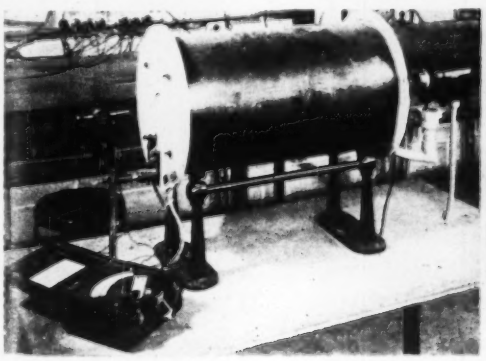
Proportioning and Proportioning-with-reset Controllers.



Calibration and Installation of Resistance Thermometers.



Density and Level Measurements.



Radiation Pyrometer Calibration and Installation.

Calibration and Installation of Thermocouples

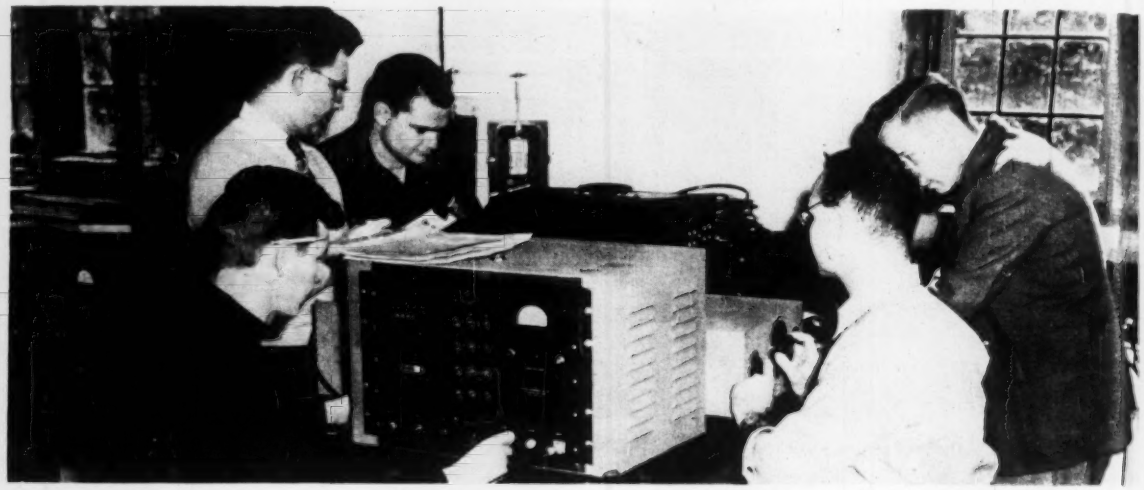


Fig. 1. Laboratory section examines wave-form of audio oscillator prior to calibration against signals from Station WWV, and starts test on new decade scaler.

Concepts *of* Instrumentation *as* Taught *at* The University *of* Tennessee

By PHILIP EWALD, Graduate Assistant, Physics Dep't, University of Tennessee, Knoxville, Tenn.

At the close of the late war, it became apparent that a specialized course in instrumentation was among the changes needed in the curriculum at The University of Tennessee in order to meet the demands of advancing technology. After considerable thought by all departments concerned and led by the Chemical Engineering Department, it was decided to have the subject taught in the Physics Department, not only because of the long-time interest and activity of this group in instrumentation, or because of the physical nature of the matter, but in order to strategically locate the course to serve all branches of science and engineering. As a result, the University Catalog now carries under the listing of Physics courses the following entry:

> 441-2-3 Instrumentation. Physical Principles of Measurement. Static errors. Dynamic errors. . . . Study of instruments and automatic controls. . . . Two hours and one laboratory period. Three hours credit, each quarter.

The course was developed and is taught by Professor John D. Trimmer, who came to the University after working on instrumentation at M.I.T. for several years under Professor Draper, and at Oak Ridge in the Electromagnetic Isotope Separation Plant and on nuclear pile control. He is author of the forthcoming book "Response of Physical Systems" (John Wiley & Co.) written as a text for the course, and of an article in the October 1949 *Scientific Monthly* on "Instrumentation and Cybernetics." Designed for students with a knowledge of calculus and elementary differential equations, the course has attracted seniors and graduate students in several branches of science and engineering, principally in physics and electrical engineering.

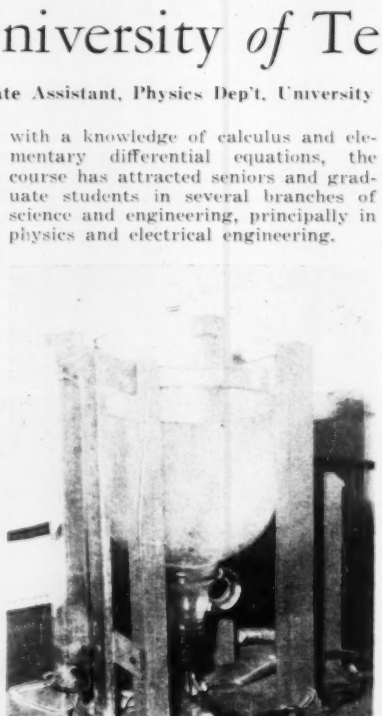


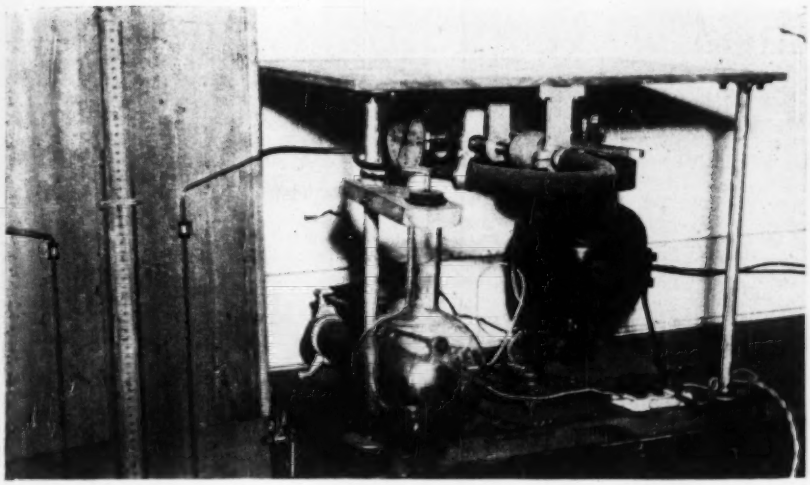
Fig. 2. Hydraulic forcer for producing first-order exponential or step function.

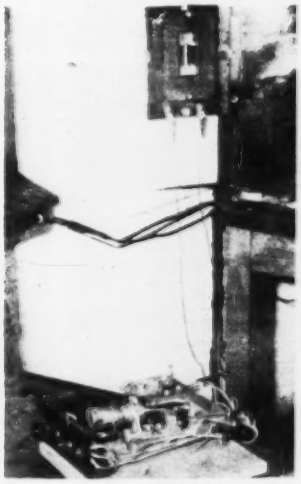
The course material covers three quarters. In the first, measurement is defined, with its limitations and effects on the measured system. Then, there follows a discussion of the three basic instrument specifications: range, efficiency* and accuracy. In connection with accuracy, the concept of random or probable error is studied in detail, including the criteria for stating accuracy of measurements.

The second quarter commences with an investigation of the response of a simple first-order system, such as a capacitance-resistance combination, to a step function, and progresses through more complicated cases such as exponential and sinoidal forcing. The study is repeated for second-order systems, as obtained for example with a capacitance-inductance combination. The idea of feedback is introduced, and the quarter concludes with a mention of higher-order distributed, and non-linear systems.

The third quarter continues with the study of system response, with increased emphasis on feedback. Methods are investigated for obtaining roots of the higher-degree equations involved.

*Editor's Note.—We believe that in Dr. Trimmer's course this term does not have the common or "engineering" meaning but is the ratio of the available energy (corresponding to the value of the measured magnitude) to the energy used in the instrument input. In some cases it is expressed as "deflection" divided by "energy," both these terms being narrowly defined. In many cases "efficiency" appears to be synonymous with the measuring property ordinarily called "sensitivity." In a few cases it is used interchangeably with "impedance." We eagerly await the appearance of Dr. Trimmer's book where this and other novel concepts will be disclosed.—M. F. BEHAR





LEFT.—Fig. 3. Motor-driven sinoidal hydraulic forcer. Water or mercury in U tubes simulates second-order system.
RIGHT.—Fig. 4. Motor-driven sinoidal electric forcer. Galvanometer coil simulates second-order system.

and then the concept of stability is considered using an approach similar to that of Routh's Rule and the Nyquist Criterion, but of a simpler nature. This last quarter presents the material which is, of course, needed to understand the operation of controls, regulators, and servomechanisms.

For each two hours of classroom work, there is one two-hour laboratory period. One of the laboratory sections is shown in session in Fig. 1. It is following the established axiom of learning: that there is no better way to learn than by doing. This is particularly true for engineers, and to be able to study the theory of probable error and then demonstrate it on the nuclear radiation counter, or to plot the theoretical response of a feedback amplifier and compare it with the action of an amplifier in the laboratory ties theory to the physical world in a rewarding manner.

Typical of the apparatus used are the forcing systems illustrated in Figs. 2, 3 and 4. All have been built in the laboratory to demonstrate certain types of response. The simplest, and first one constructed, is the hydraulic forcer shown in Fig. 2. It is a first-order system which is linear or non-linear depending on the size of capillary used, and may be used for step or exponential forcing. For this apparatus, the water levels in the jar or standpipe are the "amplitudes" of the system. Fig. 3 shows another hydraulic forcer which imparts a sinoidal action to a U-tube or other system. The apparatus of Fig. 4 is an electrical forcer which imparts, by means of a motor-driven voltage-dividing resistor connected across a battery, a sinoidal emf. to a wall galvanometer which serves in this case as a second-order system.

Closely tied in to the course are several research projects devoted to developing apparatus suitable for demonstration work. Some are carried out by graduate students working toward advanced degrees. An example is shown in Fig. 5 where a "butterfly" motor-driven capacitor, useful in simulating the action of a capacitor microphone, is under test.

While the tenor of this course may seem to be too theoretical for a study of instrumentation, particularly from an instrument user's standpoint, it represents a necessary approach to the subject for scientists and engineers who intend to work on the research and development of modern measuring and controlling instruments. Technology is advancing at such a rapid rate that the only sure way to keep pace with the trend is to attain a thorough grounding in the mathematical and physical basis of the subject and then to add a knowledge of the "hardware" or apparatus to be used in a specific case. To this end, the course has been set up so that when the engineer confronts a measurement and control problem, whether the designation is "automatic-control," "servo-mechanism," "feedback," "supply and demand," "cybernetics," or any other name, he will recognize the same old fundamentals and will be able to proceed accordingly.

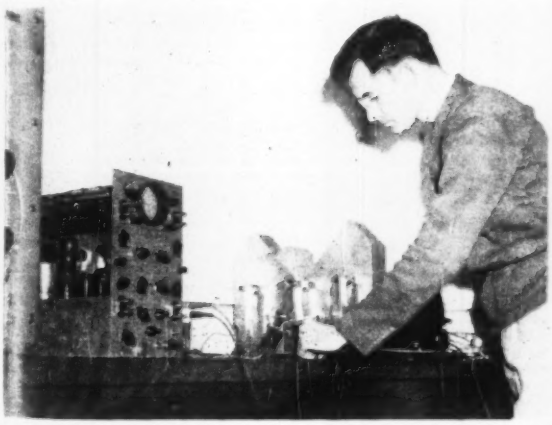


Fig. 5. Graduate student adjusts capacitor-microphone simulator.

Fig. 6. Group checks statistics of emmission from radioactive sample.

A New Method *of* Recording Flight Data

By HENRY SOSTMAN, Senior Engineer, G. M. Giannini & Co., Inc., Springfield, N. J.

INSTRUMENTATION for airborne use involves fundamental design considerations not implicit in laboratory or in fixed-location industrial equipment. Vibration conditions are always present. Accelerations of the order of 10 *G* in any direction may be encountered in piloted craft and may run much higher in pilotless planes and missiles where human toleration of acceleration is not a limit. Ambient temperatures from —76 to +149 F. and pressures from sea-level to 40,000 feet and higher are standard specifications, and transit time from one to the other extreme may be very brief. Measurement is required to a good degree of accuracy over the full range of any one phenomenon while the instrument remains insensitive to all the other conditions of its operational environment. Restrictions which do not apply to function and yet which influence design are those of size and weight, which must be held to a drastic minimum, and limited power supply—commonly direct current.

The past thirty years have seen the challenge of these rigorous conditions met with many rugged and accurate instruments capable of transmitting as electrical signals representations of flight phenomena: airspeed, pressure, altitude, acceleration, vibration, pitch, yaw, and others. The actuated members of these transmitters include voltage dividers, servomechanisms, variable inductors, etc.

The new method here disclosed was designed to provide a means of recording the output of these widely diverse transmitters with an accuracy commensurate to that of the signal. Requirements survey indicated the need for (1) multiple channels; (2) direct input without amplifiers; (3) several chart speeds; (4) continuous, separate and immediately readable traces; (5) small size and light weight; and (6) sturdiness in keeping with hard usage. Furthermore, (7) it was considered desirable to make the embodiments of the new method suitable for use with 28-volt d-c., 115-volt 60-cycle, and 115-volt 400-cycle a-c. power supplies.

D'Arsonval galvanometers were chosen as the stylus-driving elements, since they were felt to give most satisfactory sensitivity and response for their weight and input power. Permanent magnet structure was automatically indicated, for the power demand of multiple field coils would be excessive. The magnetic structure was designed as a flat rectangle to facilitate stacking several units side-by-side in limited space (see Fig. 1). The use of Alnico VI for core as well as pole pieces provides the high gap flux density of 45 kilomaxwells. The moving coil, of Formvar-covered copper wire, is supported on pivots running in jewelled bearings, and to one of these pivots is attached the stylus structure, consisting of two parallel arms of small-bore nickel tubing, flattened in the plane of the paper to provide vertical compliance and lateral stability. The moving element is completely balanced: there is no change in trace amplitude when the recorder is rotated through 360 degrees in any plane.

Galvanometer damping is a compound function. Magnetic damping is provided by winding the coil on a thin copper bobbin which is in effect a single shorted turn of low resistance, and further damping is represented by the frictional impedance of the stylus tip upon the chart paper. The motor structure produces enough torque to permit the use of very heavy restraining hairsprings, which establish a natural frequency above the range of almost all aircraft signals. To answer the need for several channel widths, three separate galvanometers were designed, with full-scale sweep of 0.75, 1.50 and 3.00 inch double amplitude for equivalent signal input. Fundamental characteristics of these galvanometers are given in Table I. Details shown as approximate are so listed because their constants depend upon transmitter as well as recorder circuits. Calibration of the recorder in terms of a given input circuit is both necessary and simple.

Extensive preliminary studies of writing media showed forcefully the need of a new approach to the matter of drawing a line.

Ink, the time-honored medium of industrial recording, is not at home in aircraft: it freezes at low temperatures, froths at high altitudes, spatters under the accelerations of maneuver, blots in excessive humidity, washes away upon submersion. Inked pens require frequent maintenance.

Colored papers coated with a thin skin of wax which is cut through by abrasion or heat offer analogous difficulties in use: wax is gummy at high temperatures and brittle at low.

Charts surfaced with plastic and marked with heat were found to give an excellent trace, but the line was obliterated by even moderate handling.

Paper sensitive to the passage of an electric current was found to represent a fire hazard and, at the light pen pressures necessary for good transient response, carbonaceous material from the paper collected on the stylus and was not rubbed off.

Film was given no consideration, since an important object was to provide an instantly readable trace that would not require the delay of processing, and possible repetition of costly test flights.

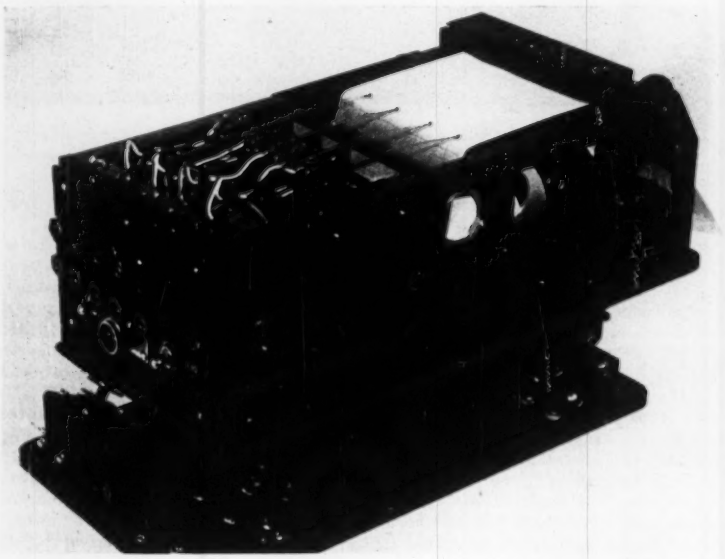


Fig. 1. Experimental but highly-developed embodiment of the new recording method. Cover and galvanometer hood removed to show the four galvanometer arms.

TABLE I.—CHARACTERISTICS

Number	A2022	A2041	A2042
Trace double amplitude, inches	0.75	1.50	3.00
Trace deflection, plus-or-minus inches	0.375	0.75	1.50
Trace width, approximate inches	0.008	0.008	0.008
Trace resolution, approximate inches	0.003	0.003	0.003
Current, approximate maximum milliamperes	10	10	10
Coil resistance, approximate ohms	160	200	240
Natural frequency, cps.	25	18	16
Response: flat within 1 percent to cps.	12	8	8
flat within 10 percent to cps.	18	12	12
Phase shift per cps., degrees	3.2	4.6	4.8
Motor structure torque, inch-pounds-radian	0.15	0.09	0.075

The answer was found in a chart paper now called Thermaline, treated with a coating of a white oxide that reduces to a black oxide at a trigger temperature of approximately 400 F. The resulting trace (see Fig. 2) is a fine black line as permanent as the basic paper stock. The record is completely unaffected by handling, and will withstand weeks of immersion in salt water. The writing stylus is a small sharp cone of sapphire suspended in a miniature heating coil, the leads to which are welded into the supporting arms. Through these, and through the heavy restraining hairsprings, heating current is passed to the tip coil. The tip assembly (Fig. 3) weighs less than 40 milligrams, and has a paper contact area of approximately three millionths of a square inch.

Recorder chart drive is accomplished by a small gear-head motor, stabilized in the d-c. model by a Lee type governor. The motor shaft works into three parallel gearsets of different ratio, which in turn drive the metering roller. Each of the parallel driven gears contains a spring-loaded pawl in its hub. To select a chart speed the drive shaft, which terminates in a knob, is pulled out or pushed in to a position established by detents, and the pawl of the selected driven gear engages a narrow ratchet cut in the drive shaft. The remaining gears are thus free to float upon the shaft. Standard gear ratios drive the paper at speeds of 0.2, 1.0 and 5.0 inches per second, driving the 250 feet of chart in 4 hours, ¾ hour and 8 minutes respectively; but the arrangement is flexible enough to permit the incorporation of almost any group of three speeds. Shifting can be done while the recorder is in full operation.

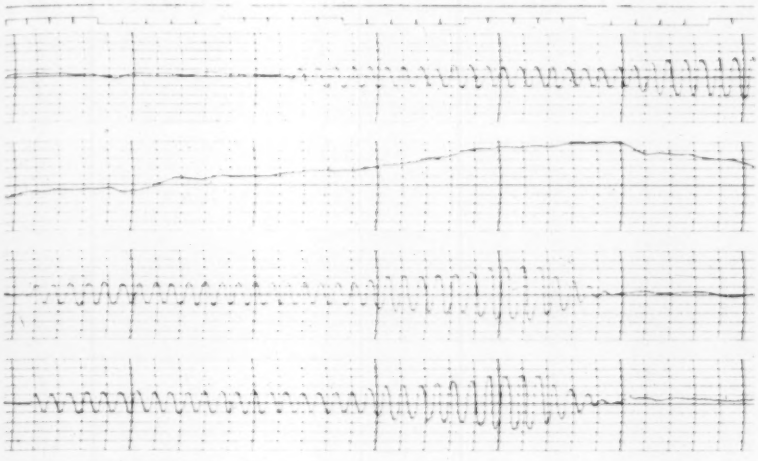


Fig. 2. The four inkless records are immediately legible without developing. The thermosensitive paper withstands tropical heat without discoloration because the white oxide does not turn black below about 400 F.

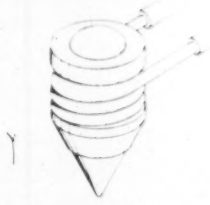


Fig. 3. Enlarged view shows sapphire cone spun into bronze shank around which is wound heating coil. Leads welded into tube assembly support the stylus. Outside diameter of the coil is 0.062. inch.

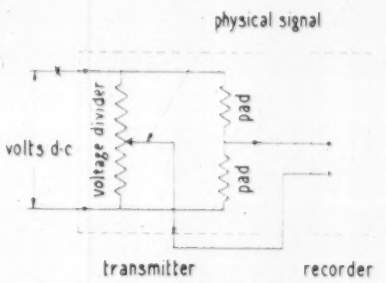


Fig. 4. A recommended input circuit for a voltage-divider transmitter is this Wheatstone bridge arrangement. A rheostat may be inserted at X to calibrate, or an Amperite regulator to stabilize voltage.

A warning light is provided to signal the approach of the end of a roll of chart, and an automatic switch stops the recorder when the paper supply is exhausted. To preclude the chance of a hot stylus standing upon stationary paper, the operational switching arrangement of the instrument is so designed that motor and stylus circuits are interlocked. Throwing either of the two switches on the terminal board to the "on" position starts the chart drive, and switching the second to "on" closes the stylus heater circuit. Throwing either to the "off" position opens the stylus circuit, and switching the other to "off" stops the drive motor. In addition, the heater circuit contains a balancing element to prevent overheating from sudden increases in line voltage.

The use of a d-c. motor in the chart-drive train posed two problems whose solution were necessary for satisfactory performance. The governed motor speed is constant with reasonable voltage fluctuation to plus-or-minus 2 percent, and if the time-axis of the record were defined by chart speed, its accuracy would be accordingly limited. Nor could several recorders (to provide a large number of simultaneous channels) be synchronized to better than these tolerances. A marking stylus was incorporated in the galvanometer bank; a stylus structure similar to the galvanometer writing member, but actuated through an amplitude of approximately 0.05 inch by a solenoid, to write a time or other on-off trace down one margin of the chart. An external time-pulse generator containing an escapement-controlled d-c. motor capable of 0.1 percent accuracy drives a keying arrangement controlling the power to the marker stylus solenoid. To write a record which can be read at a glance, the time pulse generator produces "on" switching at the rate of five pulses per second for one second, then "off" switching at the same rate for the same period, and every twenty seconds a continuous unpulsed line for one second. The time pulse generator may be employed to key the internal marker styli of any number of separate recorders, permitting accurate synchronization of many channels. The marker stylus may of course be keyed from any other switching source.

The d'Arsonval galvanometer, perhaps the fundamental electromechanical movement, is capable of circuit arrangement to register the value of almost any electrical parameter. It is anticipated that the new method will find its most usual use with voltage-divider type transmitters. These transmitters, being compact and reliable sensing elements, lend themselves to a great diversity of measurement. The signal output of a voltage-divider is a change in resistance ratio, and when the voltage-divider is wired as one half of a Wheatstone bridge with the recording galvanometer in the sensing arm (as shown in the circuit diagram, Fig. 4) measurements of a good order of accuracy are possible. Selsyns, Autosyns, and similar position-transmitting devices show change in voltage between any two taps when their shafts are rotated. Directly in the case of d-c. servos and through dry-disk rectifiers for a-c. instruments, the galavanometer in series with a suitable limiting resistance will show these position indications as a record of voltage change. The galvanometers can be used with low-output transmitters such as thermocouples and strain gages with a stage of amplification before the recorder.

In summary, the new method has been designed to write an instantly readable and relatively indestructible trace representing almost any d-c. or low-frequency signal, and to maintain accuracy under the stringent conditions of flight. Primarily intended for aircraft service, it should find application as well in other fields.

Some Application Factors Affecting *the* Regulation *of* pH *in* Industry

By ALLEN L. CHAPLIN, Consulting Engineer

IX. THE REAGENT FEED DEVICE

In general, reagent should be added at a point where it will be uniformly distributed throughout the process liquor in the shortest time possible. If a control tank is involved, there will be less effective short-circuiting in the system by addition of reagent to the inlet liquor pipe with thorough agitation before it enters the tank (Fig. 79). Piping connections from the reagent valve

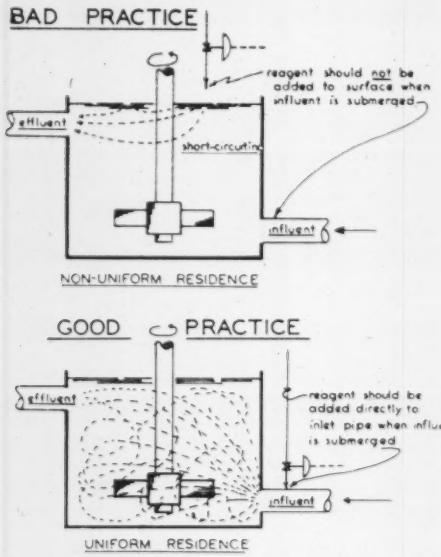


Fig. 79. Reagent should be added directly to submerged influent line of control residence. Introduction of reagent to surface of tank having top effluent enhances short-circuiting.

to point of contact with process liquor must be short as possible to avoid diffusion errors. A long discharge line from the valve to a point beneath the process liquor level, as illustrated in Fig. 80, is to be avoided since diffusion errors result from differing densities of the two liquids, especially at throttled valve positions.

In some cases it is necessary to install the valve at some horizontal distance from the point of reagent addition as illustrated in Fig. 81. To avoid transfer lags in this type of installation, the discharge line should be terminated in a "gooseneck" having a breather connection as shown. This retains a full head of liquid in the line at all times which responds instantly to changes in valve action.

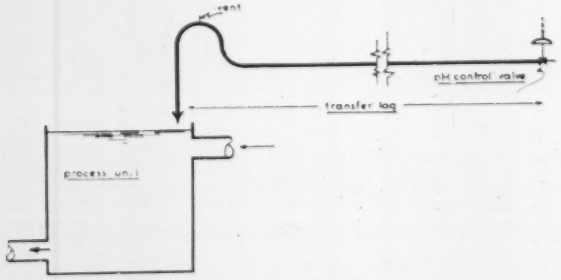


Fig. 81. Long transfer lines from remotely-located control valves must be terminated in a "gooseneck" at discharge end to retain full head of reagent in discharge line.

Valve characteristics have an important bearing on quality of control and it is usually customary to use characterized plug valves of the double-seated type, having V-port or equal-percentage characteristics with a turndown of at least 10 and preferably 50. Single-seated valves are preferred for tight shut-off, while the double seat widens the effective throttling range. Special valves are fabricated from alloy metals, plastics, hard rubber, ceramics and other materials for handling corrosive reagents.

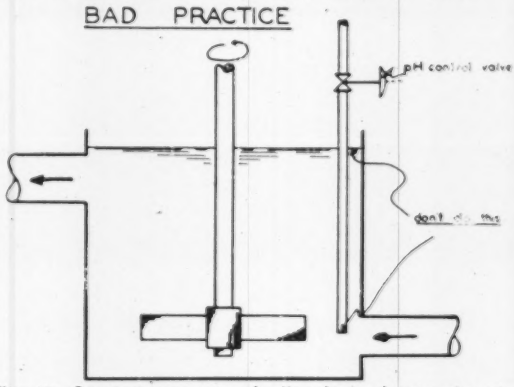


Fig. 80. Oversized reagent transfer lines having low transfer velocity should not be terminated deeply beneath tank liquid level. Diffusion errors may cause unsteady control, particularly if densities differ widely.

Valve positioners are essential on all pH control valves, especially when handling concentrated reagents in a process having high buffer index. It is desirable for the valve to move to its new position as quickly as possible (theoretically instantaneously), and hysteresis or tight packing without a positioner may delay its action. Electric valve drives have the advantage of full power application to the point of balance while air-operated units provide fast response with simplified construction.

Reagent must be supplied to the valve under greater pressure than the process pressure. In many cases this is accomplished by gravity feed from a small reagent head tank installed above the valve which, in turn, may be fed by a pump which circulates reagent from a make-up storage tank through an overflow loop as indicated in Fig. 82. If large volumes of reagent are used, thus

Continued on page 80

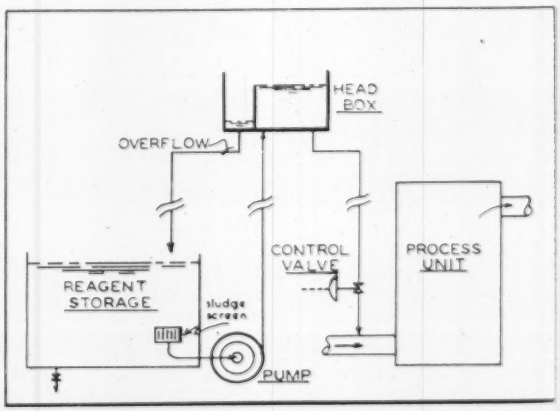
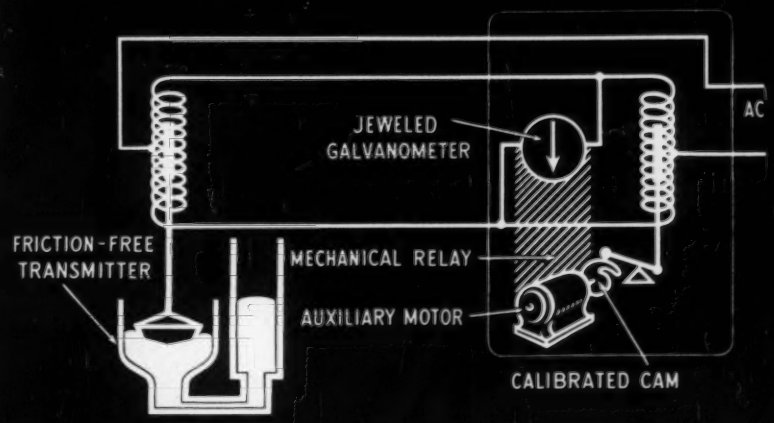


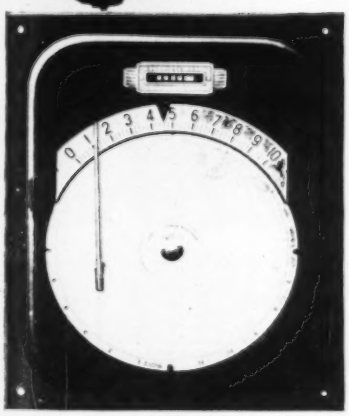
Fig. 82. Reagent supply system incorporating small-volume (5 to 10 gallon) head box and continuously-circulating reagent supply.

simple....powerful....utterly reliable

HAYS-PENN FLOW METER



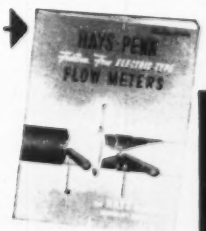
the measuring circuit does none of the operating work



Why does the Hays-Penn Flow Meter *stay accurate* and *last longer?* Simply because the friction-free transmitter serves only as a pilot—actuates an external powerful auxiliary motor which does the work of indicating, integrating and recording.

Friction is eliminated in the manometer—the float rests on the surface of mercury in the high pressure leg, positioning the magnetic core between two reactance coils. There are no stuffing boxes, no bearings, no electric contacts, no solenoid reaction.

For full details on Hays-Penn Flow Meters, for every metering need, send for Publication 43-800.



THE HAYS CORPORATION
Michigan City 8, Indiana

THE HAYS CORPORATION
Since 1905 COMBUSTION & INDUSTRIAL INSTRUMENTS & CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

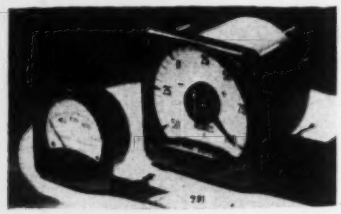
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, metering and automatic control — in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 99

Thermoelectric and Resistance Temperature Indicators

New line of temperature indicators for industrial and laboratory use includes cold-end-compensated thermocouple thermometers (up to 3000 F.)



and resistance (up to 300 F.) Thermocouple instrument is available in two sizes: "Type DO-71" with a 3.5-inch flange and "DW-71" with a 2.5-inch flange. Both types can be supplied in either square or round molded Textolite cases. Resistance instruments are available in two standard types: "DB-15" long-scale instruments; and "DD-6" and "DD-7" six-inch rectangular surface- and flush-mounted instruments.—*Meter & Instrument Div., General Electric Co., Schenectady 5, N. Y.*

Mention No. 101 when filling out card.

Miniature Thermostat

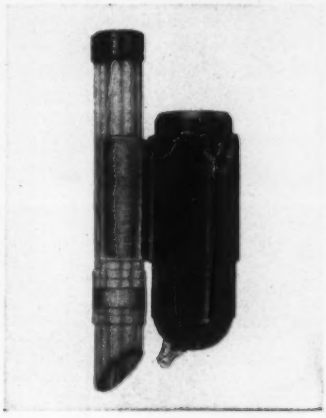
New miniature thermostat is compact; housing measures 1 by 0.31 by 0.25 in. overall, totally enclosed with wire-clinch terminal lugs. Capacity

is 100 watts ac. at 115 volts with n-o or n-c electrolytic-silver contacts. Adjustments from 0 to 400 F. are made by a single adjusting screw. Weight, 0.1 oz. —*George Ulanet Co. 410 Market St., Newark 5, N. J.*

Mention No. 102 when filling out card.

Pocket-microscope Illuminator

New illuminator for use with maker's S-129 pocket microscope, using a standard-size flashlight battery and bulb, directs an oblique beam of light on observed surface, furnishing illumination



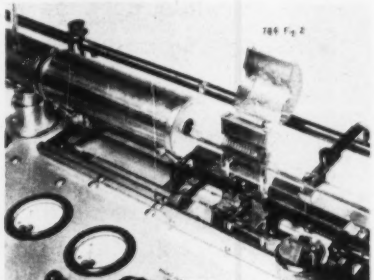
of uniform intensity throughout field. It is attached by means of a spring clip and can be removed instantly.—*Buhl Optical Co., Desk T-115, 1009 Beech Ave., Pittsburgh 12, Pa.*

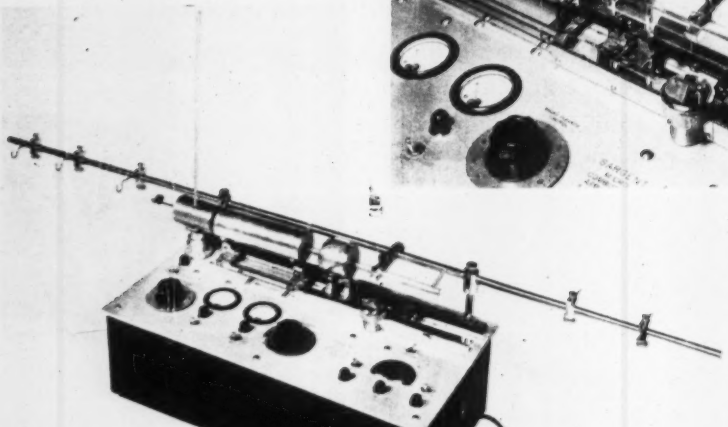
Mention No. 104 when filling out card.

Combustion Apparatus

New combustion apparatus, working with radiant transmission, heats from room temperature to 700 C. in 7 min., and from 750 C. back down in 10 min. A two-speed drive and programming control provide four different 3-phase programs, or two-phase or single-phase as selected. One sample may be burning while other is in preparation. Long furnace length is 7 in., and moving furnace 2 in. Combustion tube up to 14 mm. o.d. is accommodated. Max. temperature is over 850 C. with power of 600 watts.—*E. H. Sargent & Co., 4647 W. Foster Ave., Chicago 30, Ill.*

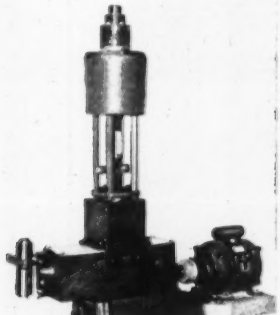
Mention No. 103 when filling out card.





Automatic Controller for Proportioning Pumps

New "Auto-Pneu-Matic" control system for proportioning pumps provides automatic volume change from zero to full displacement in response to in-

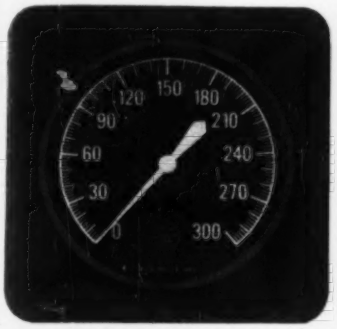


strument-air pressure change. Unit is available for use with all models of maker's proportioning pumps, and is suitable for use with all commercial pneumatic systems.—*Process Equipment Div., Lapp Insulator Co., Inc., LeRoy, N. Y.*

Mention No. 105 when filling out card.

Illuminated Dial Gage

New pressure gage has dial lighted with "black light" that glows in the dark. Case is square and for flush mounting. Dials have a black back-

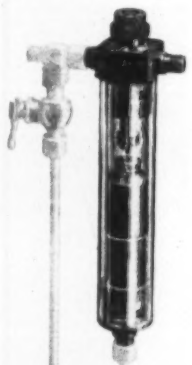


ground with ultraviolet-phosphorescent pointer, numerals and graduations, or plain white illumination may be supplied. Dimensions and features are maker's standard.—*Helicoid Gage Div., American Chain & Cable Co., Inc., Bridgeport 2, Conn.*

Mention No. 106 when filling out card.

Manostat

New model of maker's manostat, based on Cartesian Diver principle (see *Instruments*, Nov. 1947, page 1632), is designed for pressure and



vacuum control; will maintain vacuum setting even after shutting down system. Available in all-stainless or stainless with plastic-body tube.—*Emil Greiner Co., 20-26 N. Moore St., New York, N. Y.*

Mention No. 107 when filling out card.

Illumination Recorder

New illumination recorder covers a range of 0 to 10,000 foot-candles with an approximately logarithmic scale. Photocell is mounted remotely from recorder. Instrument was developed by U. S. Weather Bureau for recording daylight and is built around standard components, modified to suit measurement. For operation on 115 v, 60 cps.—*Henry A. Gardner Laboratory Inc., 4723 Elm St., Bethesda 14, Md.*

Mention No. 108 when filling out card.

Sulphur Dioxide Recorder

New "Thomas Autometer" continuously records actual concentration of sulphur dioxide in parts per million; records average concentration integrated over a half-hour period; auto-

matically checks its zero reading every thirty minutes; marks off each cubic foot of air sampled. Usual range, 0-5 ppm., covers concentrations of interest in pollution surveys.—*Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa.*

Mention No. 109 when filling out card.

Displacement-type Liquid-level Controller

New displacement-type liquid-level controller is said to control liquid level more precisely by balancing changes in buoyancy of an immersed tube with an air-pressure-loaded bellows and by transmitting this pressure to a remotely-located indicating or recording controller. New device, utilizing a forced-balanced system, is said to be particularly adaptable for petroleum and chemical processing.—*Belfield Valve Div., Minneapolis-Honeywell Regulator Co., Broad & Hamilton Sts., Philadelphia 44, Pa.*

Mention No. 110 when filling out card.

Vacuum Gage

New vacuum gage for range 1 to 1000 microns uses a noble-metal thermopile and a bridge circuit. Gage consists of an electrical indicator and a

small pickup which screws into a 0.125 in. tapped hole in vacuum system. Fast response, interchangeability of pick-ups without recalibration, freedom from outgassing and corrosion, and freedom from damage by exposure to atmospheric pressure are features. Calibration is not affected by connecting cable length.—*Hastings Instrument Co., Inc., Box 1275, Hampton, Va.*

Mention No. 111 when filling out card.

Input Control Unit for Temperature-control Systems

New "Xactline" control unit is used with any standard type or make of pyrometer controller for unusually close temperature variation control.

Unit has kept temperature variations as low as 0.2 F. and power on-off cycles as short as three seconds. Case is 8.5 in. high by 6.25 in. wide by 3 in. deep.—*Claud S. Gordon Co., 3000 S. Wallace St., Chicago 16, Ill.*

Mention No. 112 when filling out card.

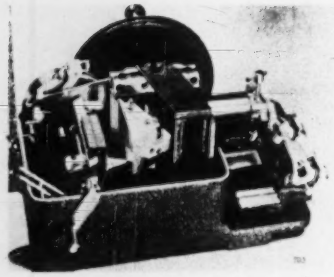
Temperature Controller

New "No. 077" temperature controller for industrial applications is said to be sensitive to "temperature changes as small as one-tenth of one degree." Its range is "between 20 degrees below zero and 300 degrees above." It is said to be immune to vibration, dust and dampness. It utilizes a wire-wound primary element which forms one leg of a Wheatstone bridge circuit. Unbalance of bridge is imposed on an electronic amplifier which amplifies and detects direction of unbalance to actuate either of two output relays, according to direction of temperature change, and thereby control a motor. Announcement states that this principle is being used successfully for temperature control on trains and street cars.—*Brown Instrument Div., Minneapolis-Honeywell Regulator Co., 4482 Wague Ave., Philadelphia 44, Penna.*

Mention No. 113 when filling out card.

Ultra-microtome

New "Pease-Baker" adaptation for "Spencer No. 820 Microtome" equipment makes it possible to cut specimens thin enough for electron microscope to penetrate. Method consists of doubly embedding tissue in celloidin and paraffin. After cutting, minute sections are picked up and placed on a microscope slide using needles or a fine brush under a low-power binocu-



lar microscope. Paraffin, and when desirable the celloidin, is then removed and specimen made ready for microscope. Sections one-127,000th in. or less are produced.—*American Optical Co., Southbridge, Mass.*

Mention No. 114 when filling out card.

Programming Control for Burners

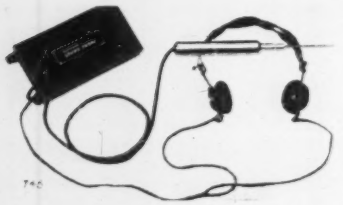
New "Type 24PJ8" programming control automatically starts burner in operation and programs sequence of fuel-valve opening, post-ignition timing, priming, and scavenging. Load

ratings: Burner motor, 1 hp.; pilot duty, 125 va.; Ignition, 250 va.: Fuel-valve solenoid, 100 va.; Gas-pilot valve solenoid, 25 va. Scavenging period, 23 sec. Ambient temp., 32 to 125 F.—*Combustion Control Corp., 77 Broadway, Cambridge 42, Mass.*

Mention No. 115 when filling out card.

Sound Probe

New sound probe localizes sound electronically, bringing it to a focal point, so it may be traced to its source. Probe brings out a natural reproduction of noise, greatly amplified and



without distortion. A particular noise in a motor or bearing may be indentified because all foreign or built-up sounds are absent. Probe is said to be so sensitive that tick of the finest watch is clear and distinct.—*Cama-Tex Co., 128 W. Lake St., Chicago 1, Ill.*

Mention No. 116 when filling out card.

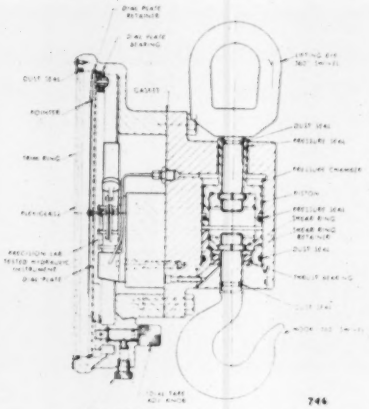
Thermoscopic Pellets, Crayons and Paints

New ratings of maker's "Tempil" pellets indicate 2100, 2200, 2300, 2400 and 2500 F. New ratings of maker's "Tempilstiks" (crayons) are available in corresponding intervals up to 2000 F. "Tempilag" paint is available in similar steps to 1600 F.—*Tempil Corp., 132 W. 22nd. St., New York 11, N. Y.*

Mention No. 117 when filling out card.

Hydraulic Crane Scales

New models of scales described in *Instruments*, Feb. '49, page 147, provide 8, 12, 24 and 30 in. dia. dials in

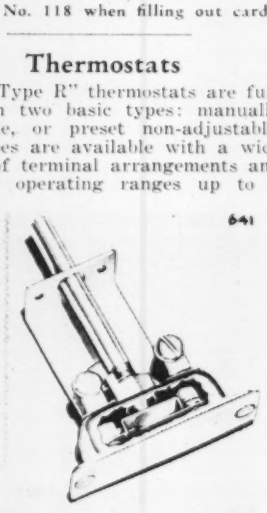


varying capacities up to 25 tons.—*Hydraway Scales Inc., 20624 W. 8 Mile Road, Detroit 19, Mich.*

Mention No. 118 when filling out card.

Thermostats

New "Type R" thermostats are furnished in two basic types: manually adjustable, or preset non-adjustable. Both types are available with a wide variety of terminal arrangements and in many operating ranges up to a



maximum of 600 F. Electrically independent bimetal strip eliminates artificial cycling and unit responds only to temperature changes in controlled device or air surrounding thermostat. Units are precalibrated before shipment in pots simulating actual service conditions.—*Stevens Mfg. Co., Inc., Mansfield, Ohio.*

Mention No. 119 when filling out card.

Combustion Furnace

New combustion furnace, equipped with a quick-opening and closing reflecting shell, permits tube filling to cool while furnace remains in pla

Helical chromel-wire element operates at temperature near that of tube filling. Max. temperature is 850 C. at 300 watts. Max. tube dia. is 14 mm. Furnace height is 9.5 in.; length of panel is 12 in.; case height is 6.63 in. and weight is 21.5 lbs.—*E. H. Sargent & Co., 4647 W. Foster Ave., Chicago 30, Ill.*

Mention No. 120 when filling out card.

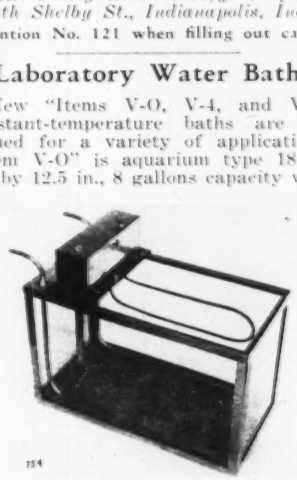
Laboratory Furnace

New "Models VH-48 and VK-48" furnaces are 10 by 8 by 18 in. and made for temperatures up to 1850 F. First model permits manual setting of power input at any point from 5 to 100 percent of full rating. Operating with a control pyrometer, both high and low temperatures may be held at close limits. Second model is designed for controlling pyrometer operation but without auxiliary control equipment.—*Cooley Electric Mfg. Corp., 38 South Shelby St., Indianapolis, Ind.*

Mention No. 121 when filling out card.

Laboratory Water Baths

New "Items V-O, V-4, and V-5" constant-temperature baths are designed for a variety of applications. "Item V-O" is aquarium type 18 by 9.5 by 12.5 in., 8 gallons capacity with



thermoregulator, heating element and coolant tube. "Item V-4" is of stainless construction 22 by 9 by 8.5 in., capacity 6 gallons, and is specially designed to hold "No. 4 Ford type" viscosity cups. "Item V-5" is same, but designed for general use.—*Henry A. Gardner Lab., Inc., 4723 Elm St., Bethesda, Md.*

Mention No. 122 when filling out card.

Laboratory Water Bath

New water bath, 15 in. diameter by 7 in. high, has a Monel exterior and tinned-copper interior. It employs two immersion-type heaters, either or both

of which can be used. Concentric rings for various sizes of flasks and a test-tube holder for up to 14 tubes are provided. A bottle-feed device prevents bath from boiling dry for as long as 10 hours on low heat and 4 to 5 hours on high heat. Weight, 24 lbs.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.*

Mention No. 123 when filling out card.

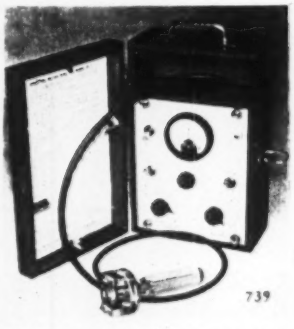
Laboratory Hot-plate

New "Temco" laboratory hot plate is available in 12 by 12 and 12 by 24 in. sizes. Temperatures can be maintained within close limits over range 140 to 850 F. and elements are of flat type which prevent cold spots. For 115 or 230 volt operation.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 124 when filling out card.

Moisture Tester for Lumber

New "Model DC-2" instrument for testing moisture content in lumber utilizes a microammeter with dual ranges from 6 to 28 percent and from



6 to 9 percent to give accuracy, particularly in the low ranges. Instrument employs megohm bridge and null principle. Temperature-correction tables are furnished, permitting readings from 40 to 240 F. Weight is 5 pounds, dimensions 10 by 6 by 4 in.—*Moisture Register Co., 133 No. Garfield Ave., Alhambra, Calif.*

Mention No. 125 when filling out card.

Voltage Regulator

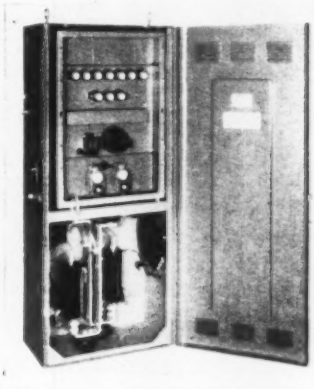
New "Type ML-8" voltage regulator supersedes "Type ML-4" step voltage regulator. It provides a total of 10 percent regulation in eight 1.25-percent steps, in any of the following combi-

nations: 10 raise, 7.5 raise to 2.5 lower, 5 raise to 5 lower, 2.5 raise to 7.5 lower or 10 percent lower. Unit is available in selected kva sizes in 2500; 5000; and 7620-volt ratings and corresponding Y-connected voltages and permits increase in current-carrying capacity up to 160 percent for connection arrangement of 5 percent raise to 5 percent lower.—*General Electric Co., Schenectady, N. Y.*

Mention No. 126 when filling out card.

Resistance Welding Controllers

Two new all-electronic high-speed resistance welding control equipments, for synchronous and non-synchronous operation, have no moving parts in power and control circuits except initiation and solenoid relays. Basic control panel consists of plug-in Rectox

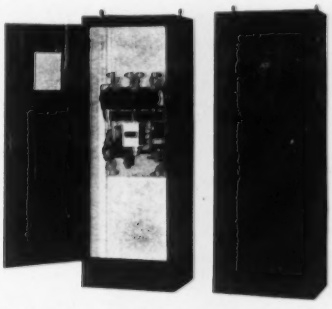


rectifier tube firing panel (for non-synchronous units) or a heat-control firing panel (for synchronous units); also sequence weld timer which controls squeeze time, weld time, hold time, and off time for a single impulse spot welding. Substitution of a precision weld-time panel for a sequence weld timer provides synchronous precision control when heat control panel is used. Auxiliary control panels are available for nine different purposes.—*Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa.*

Mention No. 127 when filling out card.

Solenoid Starters

New "Sizes 6 and 7" of "Bulletin 709" a-c. across-the-line solenoid starters have ratings in "Size 6" of 600 amp. and 200 hp. at 220 v., or 400 hp. at 440-550 v., and in "Size 7" of

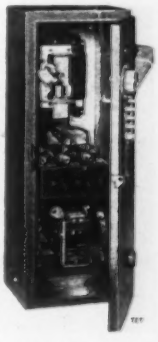


900 amp. and 300 hp. at 220 v., or 600 hp. at 440-550 v. Both models are smaller than conventional starters, steel cabinet requiring only 58 percent of usual floor space.—*Allen-Bradley Co., Milwaukee, Wis.*

Mention No. 128 when filling out card.

Motor Starter

New circuit-breaker type combination starter is designed for control of polyphase motors, 1 to 100 h. p. Interlock prevents opening door when breaker is "on", although an author-

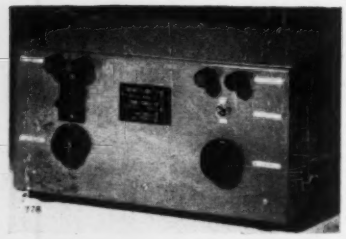


ized person can release interlock for inspection. Self-aligning handle indicates true position of breaker. Operating handle can be locked "on" or "off" with padlocks of varying sizes. Thermal (coilless) magnetic circuit breaker is non-tamperable and can be quickly reset.—*Industrial Controller Div., Square D Co., 4041 N. Richards St., Milwaukee 12, Wis.*

Mention No. 129 when filling out card.

Magnetic Amplifier

New "Type 63-1" d.c. to d.c. magnetic amplifier developed in London by Electro Methods Ltd.) has a gain constant within 2 percent with a 10 percent change in line voltage, and a zero drift over several weeks within 50 microvolts referred to input terminals. Max. power gain is 14,000, voltage gain 27, and transconductance 5 million micromhos with load resistance of 3 ohms. Max. output current is 300 ma. Amplifier makes possible use of standard indicating or record-



ing milliammeters with thermocouples or thermopiles. Reliability makes unit suitable where vacuum-tube amplifiers would be questioned.—*Trans-Sonics, Inc., Bedford Airport, Bedford, Mass.*

Mention No. 130 when filling out card.

Oven-temperature Tester

New oven-temperature tester consists of a 3.5 in. square-flange millivoltmeter mounted in a leatherette-covered case with a compartment for storing thermocouple leads and assembly. Leads are of color-coded iron-constantan wire, five feet long. Welded junction is surrounded by a radiation shield. A spring clip is attached for clamping thermocouple to oven grill. Instrument has a scale range of 0 to 650 F. and a scale length of 2.46 in. Accuracy at any set point is plus or minus 2.5 percent of full-scale value.—*Meter and Instrument Divs., General Electric Co., Schenectady 5, N. Y.*

Mention No. 131 when filling out card.

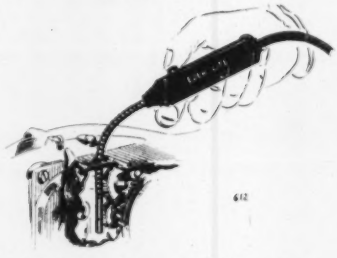
Magnetic Micrometer

New "Magnifying Micrometer" will measure coating thickness if either base or coat is magnetic, or if both are magnetic but of different permeability. A micrometer indicates tension necessary to separate a small built-in magnet from surface. Accuracy is within 10 percent for coatings thicker than 0.001 in. Calibration gages are available in non-magnetic coating on magnetic base for thicknesses from 0 to 0.08 in., and in nickel on steel or brass, 0 to 0.005 in.—*Krouse Testing Machine Co., 573 E. Eleventh Ave., Columbus 3, Ohio.*

Mention No. 132 when filling out card.

Inspection Lamp

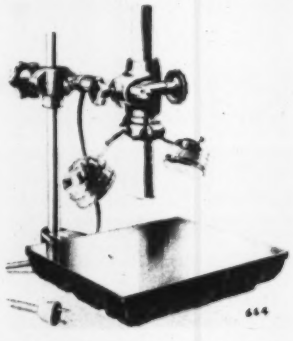
New "Eder-Lite" miniature inspection lamp for hard-to-get-at places has a 110-120 volt transformer used as a handle with a built-in switch for intermediate and constant inspection. Maximum diameter of flexible extension bulb is 0.28 in. Extensions are available in lengths of 4 to 36 inches, insulated for inspection of or between electrical wirings. Light bulbs are available in metal mounts for a forward glare-free and concentrated illumination or an exposed bulb for forward and side illumination.—*Eder Instrument Co., 1849 N. Halsted St., Chicago 14, Ill.*



Mention No. 133 when filling out card.

Surface Plate with Inspection Microscope and Illuminators

New illuminated layout plate with 16 power microscope for parts to be minutely examined or inspected features ribbed cast-iron layout plate precision ground to 0.0005 in. of true flatness. Microscope can be adjusted vertically and horizontally. Two lamps mounted on flexible tubing can be spotted on work being inspected. Microscope is 1.25 in. dia., 9.5 in. long. Eye piece and objective are achromatic coated lenses.—*All American Tool & Mfg. Co., 1014 W. Fullerton, Chicago 14, Ill.*



Mention No. 134 when filling out card.

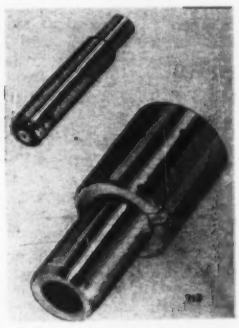
Dial Micrometer

New hand-model micrometer has been designed for portability. Dial glass covered, 2.75 in. dia., graduated in thousandths of an inch. Anvil permits calipering of thicknesses up one-half inch on sheet stock or fabricated pieces, and can be supplied in several diameters and with flat or spherical ends. An external adjustment is incorporated for maintaining dial indicator at exact zero. Lever is located for easily raising anvil for insertion of material to be measured. Anvil descends with even pressure, approximately 7 to 9 psi. (TAPPI standard).—*E. J. Cady & Co., 134 N. LaSalle St., Chicago 2, Ill.*

Mention No. 135 when filling out card.

Air-gaging Spindles

New blade-contact type air spindles for column and dial type "Precisionaires" enable an instrument-type check to be made of practically any hole regardless of finish, interruptions or size. Spindles consist essentially of a hardened-steel body slightly smaller than minimum hole size, with a hardened-steel contact blade either pivoted or floating, action of which controls flow of air through jets. Minimum size of single-blade spindles starts at approximately 0.375 in. dia. Holes having a surface finish rougher than 75 to 100 microinches can be measured accurately for out-of-round and taper as well as for diameter.—*Sheffield Corp., Dayton 1, Ohio.*



Mention No. 136 when filling out card.

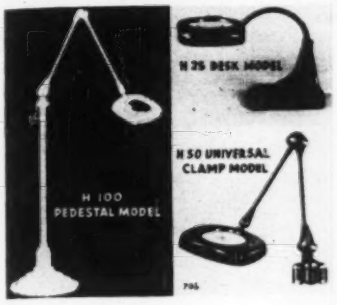
Instrument Oiler

New "Hypo-Oiler" features visible oil reservoir, extra long hypodermic-type needle for reaching inaccessible parts, and light-film or drop feed depending on pressure used.—*Gaunt Industries, 3521 N. Broadway, Chicago 13, Ill.*

Mention No. 137 when filling out card.

Inspection Magnifier

New "Magnalite" consists of a 5-inch lens set in a plastic head with 2 fluorescent lights built in on underside. Flexible-arm mountings permit instant

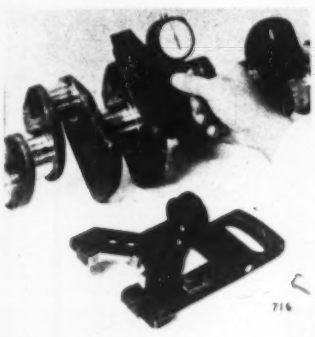


adjustment leaving both hands free to work. Special machine mounts can be made to specifications.—*Haas Corp., Mendon, Mich.*

Mention No. 138 when filling out card.

Snap Gage

New dial-snap gage features radius guides adapted to maker's standard model gage for checking parts with fillets or close to shoulders. Gage is



specifically designed for checking crankshaft grinding on machine. It has indicator graduations of 0.0001 in. Indicator may be moved to clear any eccentric throw.—*Nilsson Gage Co., Inc., Poughkeepsie, N. Y.*

Mention No. 139 when filling out card.

Container for Liquid Hydrogen

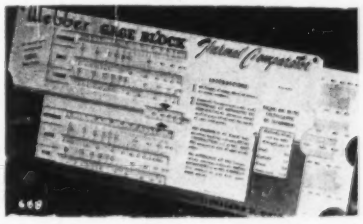
New container for storage and transport of liquid hydrogen and liquid helium is made of three concentric-copper spheres. Inner and outer spheres form a conventional vacuum flask, with facing-interior surfaces

polished to a mirror-like finish. Between them is placed a third sphere, highly polished on both sides, which acts as a radiation shield. This shield is connected to inner sphere of a smaller side flask for containing liquid nitrogen. Containers are available in 10, 25 and 50 liter capacities with side flasks holding 5, 15 and 25 liters respectively.—*Hofman Laboratories, Inc., 212 Wright St., Newark 5, N. J.*

Mention No. 140 when filling out card.

Calculator for Differential Linear Expansions

New "Thermal Comparator" slide rule gives instant reading of difference in expansion between gage blocks and work at various shop temperatures. User sets up gage-block measurement in



small window and obtains a reading that will indicate difference of expansion or contraction between block and work at 68 F. Upper half of instrument is for use with steel blocks and lower with carbide.—*The Webber Gage Co., 12900 Triskett Road, Cleveland, Ohio.*

Mention No. 141 when filling out card.

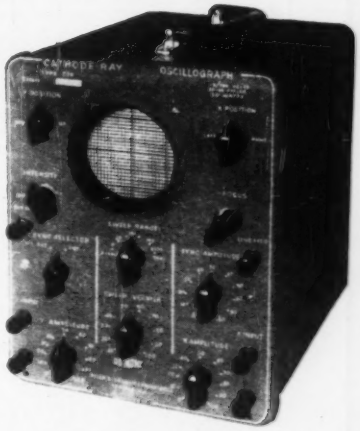
Cathode-ray Oscilloscopes

New "Types 304 and 304-H Cathode-ray Oscillographs" replace "Type 208-B." Except for higher accelerating potential of the "Type 304-H," types are identical. Recurrent and driven sweeps are variable from 2 to 30,000 cps. Slow sweeps, of 10 seconds or more, are available by connection of external capacitors between X-input terminals on front panel. Vertical deflections may be expanded to four times full-screen diameter; horizontal deflections to five times full-screen diameter. Any portion of a fully-expanded pattern may be centered on screen. Higher accelerating potential of "Type 304-H" facilitates use of long-persistence screens. Writing rates as high as 2.8 inches per microsecond may be photographed using "Type 314-A Oscillograph-record Camera" with f1.5 lens.—*Allen B. Du Mont Laboratories, Inc., 1000 Main Avenue, Clifton, N. J.*

Mention No. 142 when filling out card.

Cathode-ray Oscilloscope

New "Type 292" 3 in. cathode-ray oscilloscope weighs 21 lbs., and measures 10.88 by 8.13 by 11 in. Input signals of 0.4 rms volt and 0.56 rms volt will produce 1 in. deflection on vertical and horizontal axes, respectively. X-axis and Y-axis amplifiers supply respective pairs of deflection plates with voltages 180 degrees out of phase. Linear time-base generator provides

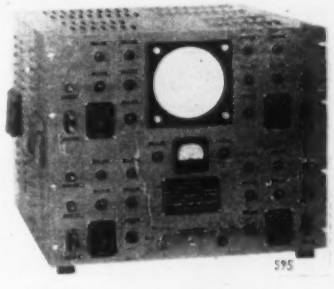


sweep frequencies from 8 to 30,000 cps, synchronized with either vertical amplifier or some external source.—*Instrument Div., Allen B. DuMont Labs., Inc. 1000 Main Ave., Clifton, N. J.*

Mention No. 143 when filling out card.

Four-channel Oscilloscope

New "Model H-43" cathode-ray oscilloscope can indicate as many as four variables on a single 5-in. flat-face tube; has been designed primarily for use with a continuous film type of recording camera. Cathode-ray tube operates at 4500 volts over-all acceleration. Photographically actinic P11 is normally supplied; other phosphors such as P5 (very short decay time) or P2 (high-voltage actinic) are also



available. Separate focus, intensity, and positioning controls are provided in each of four channels, and positioning in both horizontal and vertical directions is possible. Signal amplifiers have a frequency range from 0 to 200 kc. and a gain of about 120. Horizontal deflection can be measured in terms of volts by means of a direct-reading calibrator. Power-supplies are contained in oscilloscope cabinet and require a primary supply of 105-120 volts, 50-60 cps. Power consumption is 200 watts.—*Electronic Tube Corp., 1200 E. Mermaid Lane, Philadelphia 18, Pa.*

Mention No. 144 when filling out card.

Five-gun Cathode-ray Tube

New "55JG" tube with five independent electron guns is added to "H-21" two-gun oscilloscope (described in our Nov. issue, pages 1021-22) and to "H-43" four-gun oscilloscope (see preceding item). Guns are of zero first

Elapsed time intervals can be measured down to 1/1000th second with a

STANDARD PRECISION TIMER

The world's most accurate (and rugged) time measuring instrument. Available in 8 models as shown below:

MODEL	READS	TOTALIZES	ACCURACY
S-100	1/5 sec.	6000 sec.	± .1 sec.
S-60	1/5 sec.	60 min.	± .1 sec.
SM-60	1/100 min.	60 min.	± .002 min.
S-10	1/10 sec.	1000 sec.	± .02 sec.
S-6	1/1000 min.	10 min.	± .0002 min.
S-1	1/100 sec.	60 sec.	± .01 sec.
MST	1/1000 sec.	.360 sec.	± .001 sec.
MST-500	1/1000 sec.	30 sec.	± .002 sec.

Manually and Electrically Operated Portable Cases or Panel Mounting optional changes to conform to customers' requirements.

Special Timing Problem. **Our engineers are ready to consult with you, and design timers to meet special timing problems.**

OTHER PRODUCTS

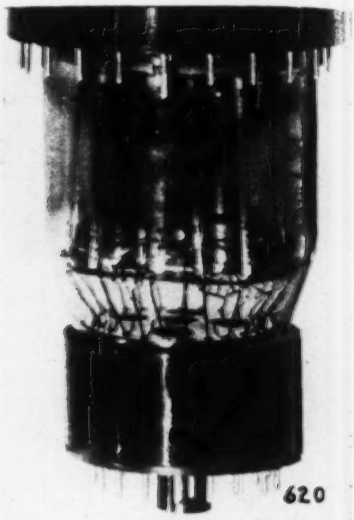
Standard Chrono-Tachometers, Custom-built Laboratory Test and Distribution Panels, School Time Program Systems, Hospital Doctor Paging and Nurse Call Systems.

WRITE FOR BULLETIN NO. 153

STANDARD

THE STANDARD ELECTRIC TIME CO.

93 LOGAN STREET **SPRINGFIELD, MASSACHUSETTS**

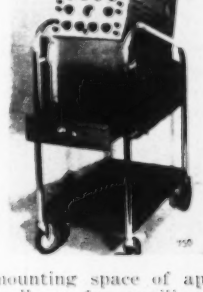


anode type with separate heater, cathode, grid, and focussing anode connections to 27-pin base. Deflection plates have separate connections to 22-pin ring around tube base, 13.25 in. from 5-in. flat-face screen. Undeflected beam from each of guns, which are arranged in circle about tube axis, strikes center of screen, which is available in standard phosphors.—*Electronic Tube Corp.*, 1200 *E. Mermaid Lane, Philadelphia* 18, *Pa.*

Mention No. 145 when filling out card

Oscilloscope Carriage

New "Type R-500 Scope-Mobile" provides a sturdy yet mobile support for oscilloscope, with 20-degree tilt-back. A blank panel, 11 x 15 in., front-



ing a mounting space of approx. 1.5 cu. ft., allows for auxiliary built-in equipment. This space is ventilated by louvres. A power input connector and three convenience outlets are located at back. A felt-lined drawer provides handy storage of cords, probes, tools, etc. Open shelf, 17 x 24 in., is topped with battleship linoleum.—*Tektronix Inc.*, 712 *S. E. Hawthorne Blvd, Portland* 12, *Ore.*

Mention No. 146 when filling out card

Megohmmeter

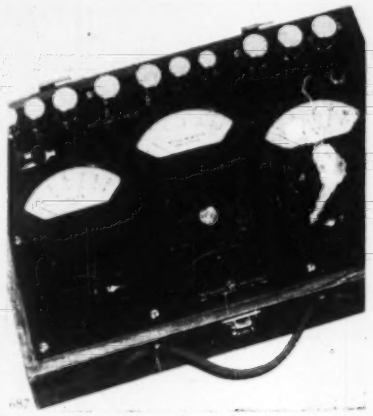
New "Model 29" megohmmeter, imported from England, covers the range 0.3 to 20 million megohms in 6 decade ranges. Test voltages of 85 and 500 d.c. are provided with short-cir-

cuit currents limited to 5 and 2.5 ma. respectively. A 6 in. mirror-scale galvanometer serves as indicator. Charging delay is about 1.5 sec. Power consumption is about 35 watts on 115 or 230 v. 60 cps. line.—*Herman H. Sticht Co., Inc., 27 Park Pl., New York, N. Y.*

Mention No. 147 when filling out card.

Industrial Electrical Analyzer

New "Model 247" portable analyzer measures electrical input to industrial loads. Ranges are: volts 150-300-600; amps. 5-25-125; and single-phase kw. ranges with basic range of 0.6 up to max. of 60 in steps. Amps and kw. may be extended with 5 amp. current trans-



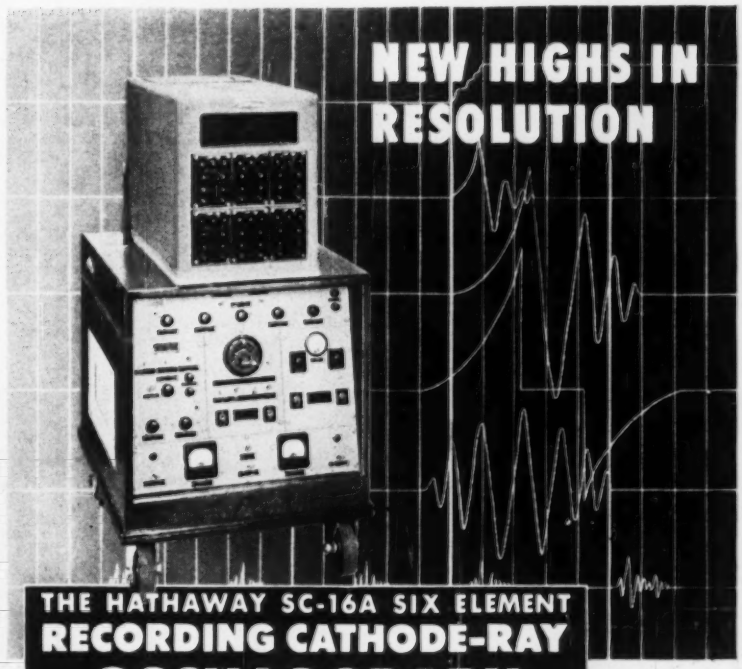
formers. Unit may be used on single-phase 2 and 3 wire, two-phase, and three-phase 3 and 4 wire systems. Accuracy of volt and ammeter is 1 percent and of wattmeter is 1.5 percent. Unit weight is 13.5 lb.; leads and case are 9 lb.—*Instrument Laboratories, 315 W. Walton Pl., Chicago 10, Ill.*

Mention No. 148 when filling out card.

Power Supply for Breakdown Testing

New "Model 224" power supply can provide voltages up to and slightly above 40 kv. d.c., with currents up to 200 microamperes. Unit can be short circuited continuously without injur-

ing any components. A kilovoltmeter indicates voltage at load. Safety features include: Output-voltage shorting solenoid when power is removed; internal interlocks on all doors; provision for external interlocks on test



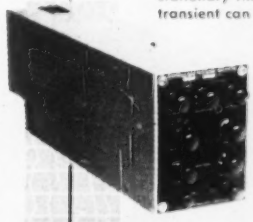
THE HATHAWAY SC-16A SIX ELEMENT
RECORDING CATHODE-RAY
OSCILLOGRAPH

NEW HIGHS IN RESOLUTION are obtained by this new oscillograph because of its unusually HIGH FREQUENCY RESPONSE and HIGH CHART SPEED...designed for recording fast transients and continuous phenomena.

FREQUENCY RESPONSE 0 to 200,000 cycles per second
RECORDS up to 1000 ft. long at speeds up to 600 inches per second
RECORDS up to 10 ft. long as speeds up to 6000 inches per second
WRITING SPEED above 100,000 inches per second

Note these additional unusual features.

- SIX ELEMENTS with convenient interchangeable lens stages for 1, 2, 3, or 6 traces on full width of chart.
- INTERCHANGEABLE RECORD MAGAZINES for CONTINUOUS RECORDING on strip chart, either 6 inches or 35mm in width up to 1000 feet in length, DRUM RECORDING for short, high-speed records, and STATIONARY CHART for very short transients.
- PRECISION TIMING EQUIPMENT, tuning fork controlled, for 1-millisecond or 10-millisecond time lines.
- Crystal-controlled Z-AXIS MODULATION for 1/10 millisecond time marks.
- QUICK-CHANGE TRANSMISSION for instantaneous selection of 16 record speeds over a range of 120 to 1.
- AUTOMATIC INTENSITY CONTROL.
- CONTINUOUS SWEEP OSCILLATOR which permits viewing as well as recording.
- Single-pulse LINEAR OSCILLATOR for recording transients on stationary film. The record can initiate the transient to be recorded, or the transient can initiate the record.



Each recording element is a complete unit, fully housed, which can be instantly inserted or removed. Recording element contains high-intensity cathode-ray tube, and both AC and DC amplifiers. Control panel is located on outside end.

FOR FURTHER INFORMATION, WRITE FOR BULLETIN 2 G-1-H

Hathaway
INSTRUMENT COMPANY
1315 SO. CLARKSON STREET • DENVER 10, COLORADO

Kester Solder

Kester engineers, with over 100,000 different types and sizes of solder available, will specify the right flux-core solder that will give maximum efficiency and economy to the job.

Easier to Use

Using the most suitable solder for each operation will enable solderers to work at top speed without sacrificing quality. Waste is eliminated and rejects are held to a minimum.

Top Quality

Kester Solders are made only from newly mined grade A tin and virgin lead. Fluxes—chemically and scientifically correct.

KESTER SOLDER COMPANY
4201 Wrightwood Ave. • Chicago 39, Illinois
Newark, New Jersey • Brantford, Canada

Send for free manual, "SOLDER and Soldering Technique."

KESTER SOLDER

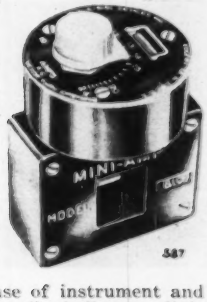
Standard for Industry since 1899

jigs, etc.; two widely separated push buttons that must be depressed to maintain high voltage continuously energized. For 117 volts, 50-60 cps., 225 volt-amps. Ripple is less than one percent.—*Beta Electric Corp., 1762 Third Ave., New York 29, N. Y.*

Mention No. 149 when filling out card.

Connectionless Ammeter

New "Model 810 burnout-proof" ammeter is rugged enough to be tossed into tool kit without damage. Current-carrying wire is slipped through open-

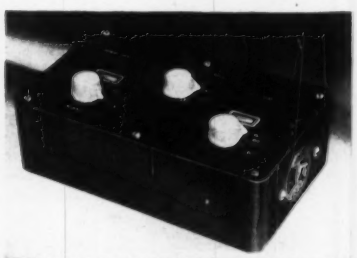


ing in case of instrument and knob is turned until indicator light extinguishes, whereupon current is read in amperes directly off dial. Range may be changed by increasing number of turns through opening. Scale range is 10-24 amperes, which may be extended down to 0.1-0.24 ampere. For 60 cycle a.c.—*Industrial Devices, Inc., Edgewater, N. J.*

Mention No. 150 when filling out card.

Circuit Tester

New "Model 900" volt-amp. tester employs two neon indicators which extinguish at volt. and amp. readings indicated by adjustable knobs. A mul-



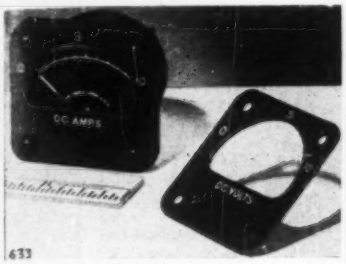
tiplying switch provides for expansion of range indicated on ammeter scale. Tester distinguishes between a.c. and d.c. Dimensions are 3.75 by 6.25 by 2 in.; weight 26 oz.—*Industrial Devices, Inc., Edgewater, N. J.*

Mention No. 151 when filling out card.

Electrical Indicating Instruments with Interchangeable Face-plates

New 1.5-in. diameter panel electrical instrument with interchangeable face plates can be used for several ranges by adding external accessories and by changing face plate. It meets Government specifications; can be supplied with either a water-tight seal or a

hermetic seal with solder-sealed terminals and crystal; as a shielded or unshielded instrument. Length of the scale arc is 1.3 in.; maker will furnish special scales to meet user's requirements. Feature is number of ranges available. D-c. self-contained instrument is said to range from 50 to 500 microamperes; from 1 to 500 ma. and

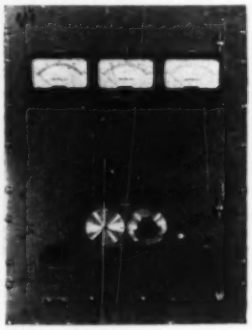


from 1 to 15 amps.; external shunts with leads permit higher ranges. Included in range are 25 to 1,000 mv. and self-contained unit will measure 1 to 500 volts, higher ranges by adding external resistors. As an a-c. rectifier type instrument, range is stated as 1 to 500 volts a.c. self-contained; higher ranges with external resistors. Accuracy is 2 percent of full-scale for d-c. operation; 5 percent when used as an a-c. instrument.—*International Instruments, Inc., 331 East St., New Haven 11, Conn.*

Mention No. 152 when filling out card.

R-f. Phase Monitor

New "Model 109" phase monitor for radio frequencies has an absolute accuracy of 1 degree and resolution and repeatability of 0.1 degree. Phase is



read directly from two dials calibrated in 0.1-degree increments. Instrument continuously and automatically indicates phase difference, hence requires no manipulation on part of operator. Provision is made to indicate antenna current in various towers of a directional array, as well as phase relations.—*Clarke Instrument Corp., 910 King St., Silver Spring, Md.*

Mention No. 153 when filling out card.

Earth-resistivity-type Ground Testers

New "Model 258A" and "Model 257A Vibropots" for earth resistivity measurements are said to "have far greater sensitivity and accuracy than heretofore considered possible in this

TYPE B HIGH PRECISION POTENTIOMETER

This general purpose potentiometer, incorporating a number of notable refinements in potentiometer design, is widely used for precise temperature measurements including thermocouple standardization, for meter calibration, for checking portable potentiometers and for other critical measurements of DC potentials requiring exceptionally high accuracy. Distinctive features include:

1. Three ranges: 0 to 1.6 volts, 0 to 160 millivolts and 0 to 16 millivolts.
2. Three reading dials—effective scale length of approximately 175 feet for each range. Readings easily estimated to within one part in 100,000 of full-scale ranges.
3. Subpanel switch and slidewire construction for protection of contacts from dust and corrosive fumes.
4. Special provisions to minimize parasitic thermal emf's—including automatic compensation of slidewire thermals and gold contacts in galvanometer key.
5. Exceptional convenience in reading and adjustment.
6. Solid and substantial construction for many years of trouble-free service.

PORTABLE PRECISION POTENTIOMETER
A two-dial instrument with built-in standard cell, galvanometer and battery, available in a variety of ranges for laboratory, plant and field applications. Described in Bulletins 270 and 270A.

Thoroughly proven by practical application in exacting research investigations for nearly fifteen years. Described in Bulletin 270.

Rubicon galvanometers suitable for use with the Type B Potentiometer are described in Bulletin 320.

OTHER RUBICON INSTRUMENTS

Galvanometers • Resistance Standards • Wheatstone, Kelvin and Mueller bridges • Evelyn Photoelectric Colorimeter for precise chemical analysis • Automatic Recording Photometric Analyzers for NO and H_2S • Magnetic Permeameters • Shorted-turn Coil Testers • Other equipment involving precise measurement of electrical quantities.

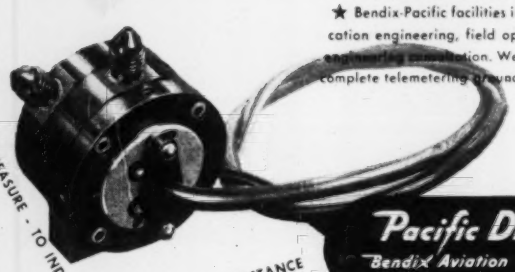
RUBICON COMPANY

Electrical Instrument Makers

3755 Ridge Avenue • Philadelphia 32, Pa.

NEW BENDIX-PACIFIC TELEMETERING PRESSURE GAGE for 0-400 PSI range

This Pressure Pickup—Assembly No. 421710 (TTP-9A)—provides a new measurement range for Bendix-Pacific AN/DKT-3 Telemetering Systems. It may be used for measurement of differential pressures or for pressures relative to a reference pressure, and may be calibrated from 0 to 5 PSI or any range between 5 and 400 PSI. Differential pressures to a maximum of ± 200 PSI may be measured. ★ Natural frequency is 500 to 2000 cycles per second with the response time dependent upon the length and diameter of the connecting tubing. Acceleration error is negligible. Weight, 0.32 lbs. ★ This new gage complements the Bendix-Pacific series of high pressure gages which range from 0 to 3000 PSI. ★ Bendix-Pacific Telemetering Systems are extremely flexible in design application and maintenance due to the use of unitized, standard dimension telemetering cases and plug-in components. ★ Bendix-Pacific facilities include installation and application engineering, field operation, data reduction and engineering consultation. We are also prepared to supply complete telemetering ground station facilities on request.



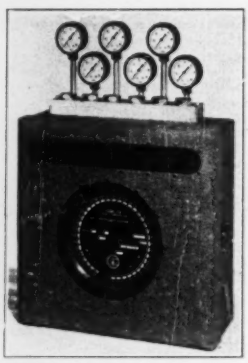
TO MEASURE - TO INDICATE - TO WARN - AT A DISTANCE

Pacific Division
Bendix Aviation Corporation
NORTH HOLLYWOOD, CALIF.

East Coast Engineering Office: 475 Fifth Avenue, New York 17, N. Y.

COSTS TOO HIGH?

ASK OUR



Representative How our **Automatic Equipment** Engineered to fit YOUR PROBLEM can SAVE YOU MONEY

We specialize in TIME CONTROLS & SEQUENCE CONTROL DEVICES. Originally designed for rubber and plastics molders they are finding increasing use in CHEMICAL and OTHER PROCESSES for sequencing complex cycles with or without TIME. Without time they may be keyed to limits of position, temperature or other measurable values.

THE "PUSHBUTTON" CONTROLLER (Illustrated) is our MODEL PB-2. It is a HIGHLY FLEXIBLE example of our many adaptable TIME SEQUENCE devices.

SEELY INSTRUMENT CO., INC.
315 FOURTH ST., NIAGARA FALLS, N. Y.
Subsidiary of Aeronautical Manufacturing Corp.

Air Operated Hydraulic Valves to 7000 psi
And Valves for Heating & Cooling Services

ONLY $215* FOR THE GREEN ENGRAVER
. . . yet it's fast, versatile and rugged enough for die steel

The Green Engraver offers great speed and convenience. Quickly cuts up to four lines of letters from 3/64" to 1" on curved or flat surfaces whether made of metal, plastics or wood . . . operates by merely tracing master copy — *anyone* can do an expert job. Special attachments and engineering service available for production work. Just the thing for radio, electronic apparatus and instrument manufacturers.

For *quality* engraving on
● Molds ● Panels ● Scales ● Dials
● Lenses ● Instruments
● Name Plates

. . . also does routing, profiling and three dimensional modeling.

**Price does not include master type and special work holding fixtures.*

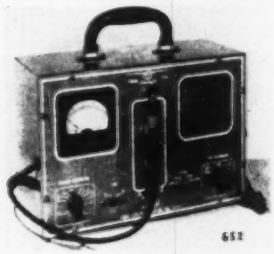
GREEN INSTRUMENT CO.
GREEN 383 Putnam Ave.
Cambridge, Mass.

type of instrument; yet are still push-button operated instrument." With an accuracy of 1 percent of the reading at any point on scale and range, "Vibropot" is a d-c. ohmmeter, an a-c. impedance bridge, applicable for earth resistivity measurements by four-point method; also provides laboratory accuracy for testing resistance to earth of man-made grounds. No correction factors are needed, and instrument is independent of auxiliary probe resistance.—*Associated Research, Inc.*, 3758 *W. Belmont Ave., Chicago* 18, *Illinois.*

Mention No. 154 when filling out card.

Signal Tracer

New "Model 777A Dynatracer" signal tracer has input capacity of only 3 micromicrofarads. Attenuation is 10,000 to 1 by means of a ladder attenuator with vernier control. Sensitivity is 10,000 microvolts for full-scale deflection or 200 microvolts per



division. Frequency range covers approximately 160 Mc. A jack is provided for testing microphones and pickups. Automatic-control switch permits either speaker or indicator to be used alone or together or standby.—*Radio City Products Co.*, 152 *West 25th Street, New York* 1, *N. Y.*

Mention No. 155 when filling out card.

Timing Motor

New self-starting synchronous motors feature high-temperature Glyptol sealing for gear case, hardened-stainless steel rotor shaft, aluminum rotor, and nylon first-reduction gear. Gear-

train housing is dust proof. Rotor is visible through a window. Optional two-way friction clutch has torque of 9 oz.-in., plus or minus 3 oz.-in. Output shafting and speeds according to specifications. For 120 or 240 v. at 60, 50, or 25 cps. Power used, 2.25 watts.—*International Register Co.*, 2616 *W. Washington Blvd., Chicago* 12, *Ill.*

Mention No. 156 when filling out card.

Filterless Dust Collector

New "Model 30N50 Dustkop" develops 3630 cfm. (velocity 10,400 fpm.); measures 28 x 49 in. floor space

82 in. over-all height; thus combines high volume with small space requirements. A self-clearing paddle-wheel fan is direct-driven by a 5-hp. continuous-duty motor. Dust-laden air enters unit at 8-in. diameter inlet. Dust, etc., is taken out in cyclone separator and deposited in dust storage compartment which has 12 cu. ft. capacity and forms base of unit. Cleaned air, with any toxic fumes, objectionable smoke, etc., is exhausted to outdoors through outlet at the top of cyclone. Ordinary sheet-metal pipe can be used to complete installation. Additional advantage claimed for this type of equipment is that it is available from stock. —*Aget-Detroit Co., Ann Arbor, Mich.*

Mention No. 157 when filling out card.

Exposure Meter

New "Red Dot" exposure meter utilizes photometric principle: a calibrated lamp illuminates half of a comparison screen, other half is illuminated by light from the scene. When halves are matched (by moving a lever) light value is indicated. From this, proper exposure is found as usual on a circular dial. Instrument is designed for one-hand use, is slightly smaller and thinner than a pack of cigarettes, resembles a photoelectric type exposure meter but its price is almost one-fourth that of photoelectric types. It is calibrated for film speeds from 6 to 400 ASA and has a range of shutter speeds from 2 seconds to 1/800th, apertures from f:1.4 to f:45. Exposure indications are said to be accurate for all normal photographic uses, both indoors and outdoors. Lamp is run at less than normal voltage and, according to announcement, may be expected to hold its calibration "over a long period of time." Two special pen-light batteries (photoflash type) are easily replaced but "do not require frequent change" since drain of lamp is low.— *Lloyd Mfg. Co., Houtzdale, Penna.*

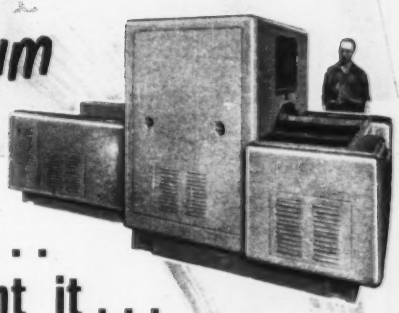
Mention No. 158 when filling out card.

Statistical & Quality-Control Slide Rule

New slide rule, developed in accordance with basic principles of quality control adopted by American Standards Association in Standard Z 1.3 "Controlling Quality During Production," has traditional log-log scale arrangement, specialized quality-control scales, and ordinates and areas for the normal curve. Rule is 12.125 by 2 by 0.156 in. and weighs less than 4 oz. Non-warping light-metal core with op-

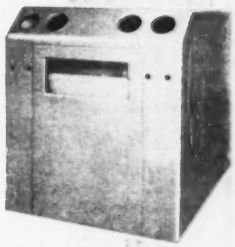
CUSTOM-BUILT

Cubicles, Cabinets and Control Boards by Kirk and Blum



As you want it . . .
when you want it . . .

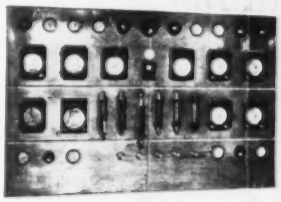
Gauges from 3/8" or lighter



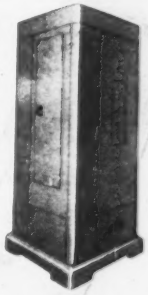
Whatever your requirements in electrical enclosures KIRK & BLUM is equipped to fabricate them to your most exacting specifications. Whether it's a single unit . . . or hundreds . . . KIRK & BLUM has the organization, experience and facilities to do a first class job.

Sheet metal units fabricated by KIRK & BLUM follow the customer's specifications accurately, down to the last detail.

We specialize in custom-built parts and assemblies of Sheet Steel and Light Plate, Stainless, Aluminum, Monel, and other alloys.



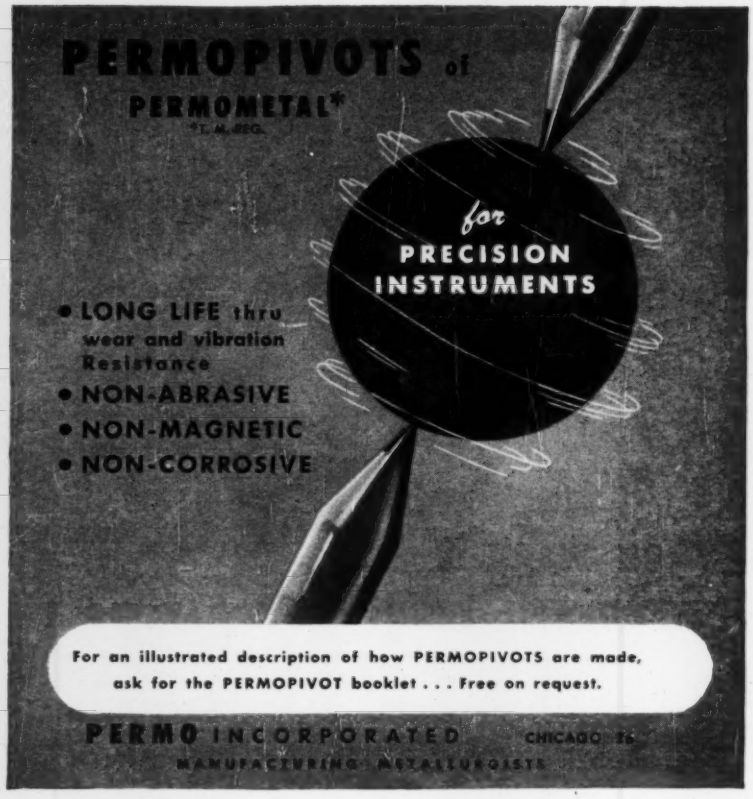
Send your prints for prompt quotation to THE KIRK & BLUM MFG. COMPANY, 2911 Spring Grove Avenue, Cincinnati 25, Ohio.



KIRK AND BLUM

MADE TO YOUR EXACT SPECIFICATIONS

- CONTROL DESKS AND PANELS
- SWITCH GEAR HOUSINGS
- CUBICLES
- TRANSFORMER HOUSINGS AND TANKS
- ELECTRICAL ENCLOSURES
- VENTILATING LOUVRES



GIANNINI PRESSURE TRANSMITTERS

— proven in aircraft and guided missiles

NOW available for industry — for remote recording, control or indication.

Ranges from 1 to 10,000 psi

Standard units $96.00

Write for complete information

G. Giannini & Co. Inc.
285 W. Colorado, Pasadena 1, California
697 Morris Turnpike, Springfield, N. J.

High Precision Optical Components Any Size For Astronomical and Physical Research

•

Parabolic, Spherical, Ellipsoidal and Plane Mirrors

•

Plane Parallel Plates

•

Schlieren Systems

•

Interferometer Plates

•

Lenses and Prisms of Glass

•

Natural or Synthetic Crystals

•

Complete Optical and Mechanical Instruments

•

Made to Specifications

•

High Vacuum Coating

•

John Unertl Optical Co.

3551-3555 East Street
Pittsburgh 14, Penna.

tical tongues and grooves insure permanent alignment, freedom from distortion, easy operation.—*Pickett & Eckel, Inc., 5 S. Wabash Ave., Chicago 3, Ill.*

Mention No. 159 when filling out card.

Rain Gage

New rain gage consists of Tenite plastic tube, a metal frame with graduated scale cut into metal, and a metal cup to funnel rain into tube. Tube will measure up to 6 in. rain without having to be emptied. Readings are

made directly in inches and tenths, and in hundredths by interpolation. All parts are proof against rust or corrosion. A book in which an eleven-year record of rainfall can be kept is included.—*Victor Rain-Gage Co., Airport Branch, Wichita, Kansas.*

Mention No. 160 when filling out card.

Educational Amplistat

New educational amplistat, operating from 115-v., 60-cps line, consists of a saturable reactor and rectifiers mounted in one unit. Assembly is fast-

ened to surface of a textolite panel which has a schematic diagram of component parts molded in its surface. Reactor consists of two main cores each wound with a load winding and four control windings linking both cores.—*Special Products Div., General Electric Co., Schenectady 5, N. Y.*

Mention No. 161 when filling out card.

Smoke Density Indicator

New "Type 2A10C" smoke indicator consists of: photoelectric control, light source, and densometer. First two are

MODERN
ELECTRONIC
ENGINEERING
GIVES
PRECISE

FINGERTIP SPEED CONTROL

- TACHOMETER PROPORTIONING
- TENSION OR POSITION CONTROL
- MOTOR INTEGRATORS
- BI-DIRECTIONAL
- DYNAMIC BRAKING
- SERVO CONTROL

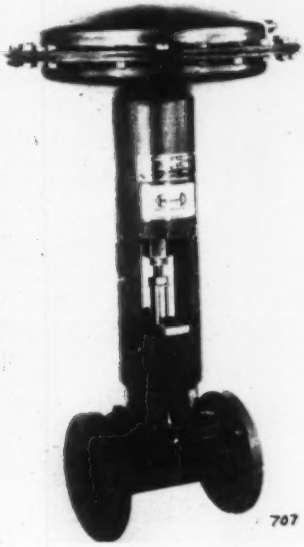
Servo-Tek products co
4 Godwin Ave. Paterson, N. J.

mounted on opposite sides of flue or breeching. Beam from source projects from an opening in flue to eye of control. Densometer is located on boiler-room instrument panel—*Photoswitch Inc., 77 Broadway, Cambridge 42, Mass.*

Mention No. 162 when filling out card.

Diaphragm-pinch Valves

New "2000 Series" diaphragm-control valves are available for any size up to 12 in. They are designed primarily to handle corrosive fluids or

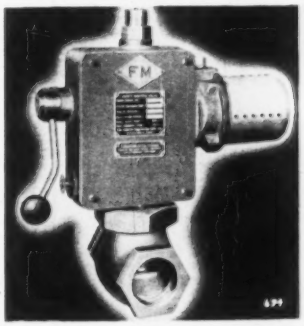


gases or any slurry or fluid carrying solids in suspension. Operating temperature is limited by diaphragm material used, 180 F being considered max. safe figure. Body through 4 in. size is rated at a max. working pressure of 150 psi; 5 and 6 in. for 125 psi; 8 in. at 100 psi; and 10 and 12 in. for 65 psi.—*Hammel-Dahl Co., 243 Richmond St., Providence 3, R. I.*

Mention No. 163 when filling out card.

Shutoff Valve

New "Series 21" safety shutoff valve stops flow of any gas or liquid instantly when current to solenoid is



interrupted. When power is restored, valve is reset manually. It may be tripped closed manually if desired and cannot be wedged or propped open

MAGNA-SIGHT
Low-Cost, pipeline
FLOW GAUGE

for flow rate indication

A magnetic roller, entirely outside the fluid stream, indicates flow rate on a graduated scale.

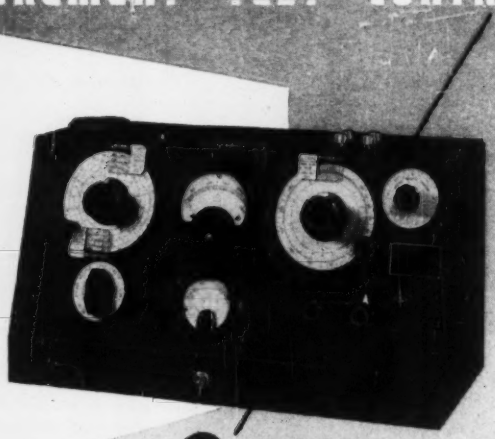
FOR—Clear or opaque fluids, slurries
CAPACITIES—3.5 to 250 gpm; 10 to 1 range
PRESSURES—to 500 psig
TEMPERATURES—to 400° F
MATERIALS OF CONSTRUCTION—Brass, Bronze, Iron, Steel, Stainless Steel (type 316)
ACCURACY 5% average over scale range
SCREWED or FLANGED connections

MAIL THIS COUPON TODAY!

PLEASE SEND CATALOG 96
Name.....
Title.....
Company.....
Street.....
City..... *State*.....

FISCHER & PORTER CO.
Dept. OL-5C Hatboro, Pennsylvania
PROCESS CONTROL INSTRUMENTS

MEASUREMENT • TEST • CONTROL



160-A Q METER

The 160-A Q-Meter is unexcelled for laboratory and development applications, having received world wide recognition as the outstanding instrument for measuring Q, inductance, and capacitance at radio frequencies.

Frequency Range: 50 kc. to 75 mc. (8 ranges)
Q Measurement Range: 20 to 250 (20 to 625 with multiplier)
Range of Main Q Capacitor: 30-450 mmf.
Range of Vernier Q Capacitor: +3 mmf., zero, —3 mmf.

For further specifications and descriptive details, write for Catalog F

BOONTON RADIO
BOONTON N.J. U.S.A.

The *Accurate* Way to Measure Extreme Temperatures *at a glance*

The Simplified PYRO Optical Pyrometer

SELF-CONTAINED. No correction charts, no accessories, no up-keep. *Direct-reading.*

ACCURATE. Permits *close* and *rapid* temp. determination — even on *minute spots, fast-moving objects, smallest streams.* "Special Foundry Type" and "Triple Range" also have RED Correction Scale for determining *true spout* and *pouring* temps. of molten iron, steel in the open.

LIGHT IN WEIGHT — Only 3 lbs. complete. Handy.

PROVED IN USE—Foundrymen all sweat by it.

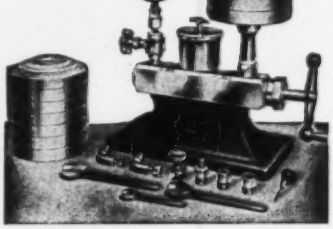
Stock Ranges 1400°F. to 7500°F.

Write for FREE Catalog No. 30 — also catalogs on other PYRO Pyrometers

THE PYROMETER INSTRUMENT CO.
Plant and Lab.
BERGENFIELD 4, NEW JERSEY
In Canada, Sales and Repair Laboratory:
Dominion Flow Meter Company Limited
Toronto and Montreal

AMTHOR Dead Weight Pressure Gauge TESTER

Type 452



Modern design and construction puts this rugged precision instrument in a grade above the ordinary dead-weight testers.

Made in ten ranges, to 5000 lbs. maximum.

We guarantee 1/10 of 1 percent accuracy in each range.

The Type 452 is designed for simplicity and compactness. It incorporates the newest refinements and improvements. Adapters and tools are supplied, as well as either carrying case or protecting cover.

Immediate and intelligent attention will be given to your inquiries on all industrial speed measurement problems.

Drop us a line today.

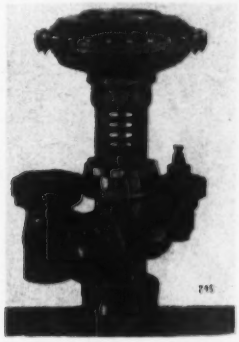
Amthor
Testing Instrument Co., Inc.
49a Van Sinderen Ave. Brooklyn, N. Y.

with power off since resetting handle is independent of valve stem. Globe-type soft-seating valve can be had with all-iron body and internals, available in sizes from 0.75 through 6 in., with solenoids for 110, 220, 440 volts and 60, 50 and 25 cps.—*The North American Mfg. Co., 4455 E. 71st St., Cleveland 5, Ohio.*

Mention No. 164 when filling out card.

Two-pressure Hydraulic Valve

New larger size of "Series 805" valve in 2.5 and 3 in. sizes, for example, is valuable in controlling hydraulic-cylinder operated machinery, which is operated from low pressure to produce long strokes economically fol-



lowed by application of high pressures from 2000 to 5000 psi. to produce necessary working tonnage. Valve is poppet type throughout, all seats and disks of hardened stainless steel. Seat rings and disks are removable for replacement. Action of three-way valve is balanced, and balancing pistons pass through molded-mechanical packers. Bodies are of heavy-walled bronze castings to 3500 psi. service and for higher pressure of stainless steel.—*Seely Instrument Co., Inc., 377 Fourth St., Niagara Falls, N. Y.*

Mention No. 165 when filling out card.

Solenoid Valves

New line of solenoid valves have internal parts of brass and stainless steel, with packless-type heavy-duty

solenoid for pressure from 0 to 300 psi. and temperature 0 to 500 F. Valves are built for water, air, steam, gas and custom requirements.—*A. A. A. Valve Co., Inc., 357 Canal St., New York, N. Y.*

Mention No. 166 when filling out card.

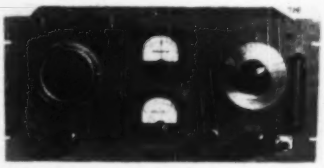
Control Transformers

New control transformers follow closely proposed NEMA standards; are particularly adapted to inductive low-power-factor loads of solenoids, relays, and contactors. Secondary voltage of 60-cycle units remains above 90 percent of rated voltage up to a load current of seven times normal at 20 percent load power factor. Seven sizes from 0.075 to 1.5 kva. are available for 220/440 volts primary to 110 volts secondary at 60 cycles. For 50-cycle operation, six sizes from 0.15 to 1.5 kva.; for 25-cycle operation, three sizes from 0.15 to 0.5 kva.—*Westinghouse Electric Corp.*, 306 *Fourth Ave., Pittsburgh* 30, *Pa.*

Mention No. 167 when filling out card.

Radio-telemetering Receiver

New "Model 167" vhf receiver, designed as terminal equipment in telemetering systems has a frequency range of 210 to 250 Mc. Provision is



made for audio monitoring and for feeding a series of subcarrier discriminators. All transformers and meters are hermetically sealed, and no electrolytic condensers are used. Receiver is treated to resist moisture and fungus growth.—*Clarke Instrument Corp.*, 910 *King St., Silver Spring, Md.*

Mention No. 168 when filling out card.

Copper-oxide Rectifier

New "Model CX14" copper-oxide rectifier features a gold-to-gold internal circuit arrangement made up of vacuum-processed rectifier plates with

gold contacts, specially-treated gold terminals and copper-alloy brackets. Impregnated and sealed to withstand extreme humidity, unit is also fungus resistant. Dimensions are 0.5 by 0.18 by 0.25 in., mounted on a 2-56 by 0.375 screw.—*Bradley Laboratories Inc., New Haven, Conn.*

Mention No. 169 when filling out card.

Electrolytic Capacitors

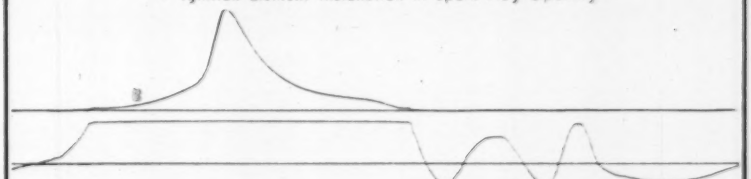
New "Type SRE" electrolytic capacitors in miniature sizes are hermetically sealed in tubular-aluminum cases with wax-impregnated cardboard-insulating jackets. Stud terminals provide max. creepage distances between terminals and can. Despite diminutive size, they comply with RMA tolerance requirements, d-c. leakage-current limits, surge-voltage ratings, operating-

Want the INSIDE STORY?

The Cox Direct Pressure Engine Indicator tells *more of the true* INSIDE STORY of any engine.

Here are REASONS WHY it is an important tool for engine design analysis:

- Pressure Recording and Indicating in All Engines
- Direct Measurement at Instant of Pressure Balance
- Gas Sampling with Same Equipment
- Simultaneous Diagrams from All Cylinders
- Full Scale High and Low Pressure Cards
- Plain Pressure Elements for All Engines
- Ignition Element Installation in Spark Plug Opening



Unretouched (quarter-size) high and low pressure diagrams and atmospheric line taken with only one element in the combustion chamber. Manifold and exhaust pressure diagrams taken at the same time are not shown. Above card is typical of the unique flexibility and accuracy of the equipment for studying cylinder and manifold pressures and gas samples to determine combustion analysis, mixture ratio, stratification, turbulence, scavenging, peak pressure, pressure rise, mean effective pressure, valve pressure drop, exhaust back pressure and pulsation.

For the **true** INSIDE STORY, use a Cox Direct Pressure Indicator to determine conditions inside the cylinders and manifold . . . Where performance starts.

Write for Catalogue IM-2

COMMERCIAL RESEARCH LABORATORIES, DETROIT 3, MICHIGAN

Makers of COX INSTRUMENTS *Since 1912*

one-second zero setting with revolving dial and external knob

HEISE GAUGES

STANDARD OF THE WORLD

Zero adjustment in Heise Bourdon pressure gauges is simply a matter of turning an external knob with the fingers. No tools are needed. Nothing is removed. The knob rotates the dial until zero and pointer coincide. Direct readings of absolute pressure can be made by setting the dial to agree with barometric pressure.

Three sizes: 8½ in., 12 in., and 16 in., in ranges from 0-15 to 0-10,000 psi. Prices from $151.60 to $211.20. Write for catalog.

Heise Bourdon Tube Company, Inc.
Newtown, Connecticut

S·S·White MOLDED RESISTORS

The All-Weather Resistors

ARE USED IN THIS ULTRA SENSITIVE ELECTRONIC PHOTOMETER

In this instrument—designed for measurement of very low light values—S.S.White Resistors serve as the grid resistance in the all-important high-gain D.C. amplifier circuit. The manufacturer, Photovolt Corp., New York, N. Y., reports that the resistors "work very satisfactorily"—which checks with the experience of the many other electronic equipment manufacturers who use S.S.White resistors.

S.S.WHITE RESISTORS

are of particular interest to all who need resistors with inherent *low noise level* and *good stability* in all climates.

HIGH VALUE RANGE
10 to 10,000,000 MEGOHMS
STANDARD RANGE
1000 OHMS to 9 MEGOHMS

WRITE FOR BULLETIN 4906

It gives essential data about S.S.White Resistors, including construction, characteristics, dimensions, etc. Copy with price list on request.

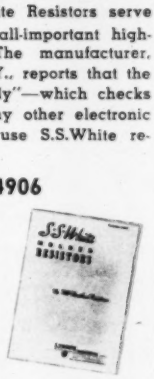


Photo courtesy of Photovolt Corp., New York, N.Y.

S.S.WHITE INDUSTRIAL DIVISION
THE S. S. WHITE DENTAL MFG. CO. — DEPT. I — 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS AND ACCESSORIES
MOLDED PLASTICS PRODUCTS—MOLDED RESISTORS

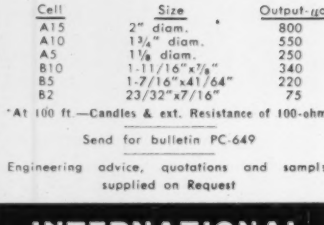
One of America's AAAA Industrial Enterprises

SELENIUM PHOTOELECTRIC CELLS

Self-generating — No external power source required.

Sensitivity — Up to 600 microamps per lumen.

Stable Characteristics - Long Life



Cell	Size	Output-μa*
A15	2" diam.	800
A10	1¾" diam.	550
A5	1⅛ diam.	250
B10	1-11/16"x⅞"	340
B5	1-7/16"x41/64"	220
B2	23/32"x7/16"	75

*At 100 ft.—Candles & ext. Resistance of 100-ohms

Send for bulletin PC-649

Engineering advice, quotations and samples supplied on Request

INTERNATIONAL RECTIFIER CORP.
6809 S. Victoria Ave.
Los Angeles 43, California

THE NEW
BERKELEY
MODEL 700
DECIMAL COUNTING UNIT

This unique packaged component is *easily built into* your apparatus. It has *true decimal reading*, and simple binary circuit with reliable *automatic interpolation*. Miniature size. Moderate price. Immediate shipment.

Send for Bulletin DCU-114

Berkeley Scientific Company
SIXTH AND NEVIN AVE · RICHMOND, CALIFORNIA

temperature ranges, etc. Life is comparable with that of larger electrolytics.—*Aerovox Corp., New Bedford, Mass.*

Mention No. 170 when filling out card.

D-c.-drive Choppers

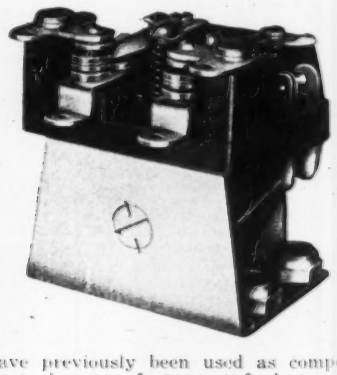
New self-excited choppers are a combination of s-p. d-t. and s-p. s-t. choppers mounted together in one hermetically-sealed high-permeability container on an 8-pin octal base. Coil is for 6 or 26 volts at 1.5 watts. Contacts nominally handle 10 volts at 0.001 amp.

d-c., or higher values for intermittent duty. Vibration frequency is 120 per sec. Choppers are useful as modulators, rectifiers, demodulators, or square-wave generators for low-level signals from thermocouples, strain gages, or servomechanism error voltages.—*Stevens-Arnold Inc., 22 Elkins St., S. Boston 27, Mass.*

Mention No. 171 when filling out card.

Relays

New line of electrical relays, headed by compact general-purpose "BO" model, will be available from retail outlets throughout country. Relays



have previously been used as components by manufacturers of electronic and electrical equipment.—*Allied Control Co., Inc., 2 East End Ave., New York 21, N. Y.*

Mention No. 172 when filling out card.

Multiplier Phototube

New "5819" multiplier photo-electric tube is specially designed for use with scintillation counters. With a "head-on" cathode measuring 1.5 in. dia., a sen-

sitive area several times that of previous models is attained. The resolving time of less than one-hundred millionth sec. is considerably faster than that of Geiger tubes. Effective spectral sensitivity ranges from near ultra-violet to orange.—*Tube Dep't, Radio Corp. of America, Camden, N. J.*

Mention No. 173 when filling out card.

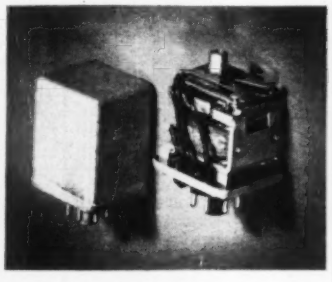
Multiplier Phototube

New characteristics of maker's "1P21" multiplier phototube reduce equivalent noise input to 5 x 10^{-18} lumen, a sixfold improvement in performance. Tube is particularly suited to use in spectrometers, astrotelescopes, scintillation counters and other equipment where collimated-light beams are employed.—*Tube Dep't, Radio Corp. of America, Harrison, N. J.*

Mention No. 174 when filling out card.

Miniature Relay

New "Frame 181" relay structure offers maximum resistance to mechanical stress. Balanced armature minimizes false contact operation under shock and vibration. Relays have ap-



proximately 50 percent more coil volume than existing types of comparable size, and magnetic structure has two working air gaps. Any contact arrangement up to 4-pole d-t. can be furnished as a standard open-type relay or with plug-in base and removable or hermetically sealed metal cover.—*Struthers-Dunn, Inc., 150 N. 13th St., Philadelphia 7, Penna.*

Mention No. 175 when filling out card.

A-c. Electrolytic Capacitors

New "Type 11A" electrolytic capacitors for 115-volt continuous-duty a-c. service may be used in applications where starting-voltage surges across capacitors may exceed rated voltages by as much as 50 percent for a maximum of two seconds. Another important use is where a voltage drop is required without power dissipation.—*Sprague Electric Co., North Adams, Mass.*

Mention No. 176 when filling out card.

Refractive-index Recorder

CORRECTION

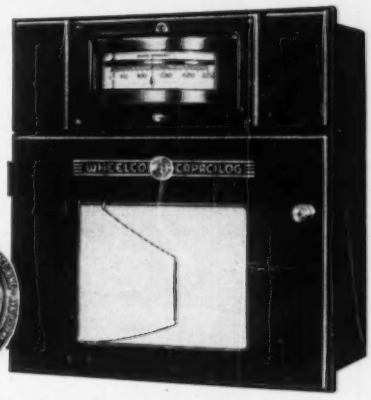
Item No. 1208, page 1109 of our December issue:—A line of type was dropped out at the end, which should read as follows: "34 in. high, 24 in. wide.—*Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.*"

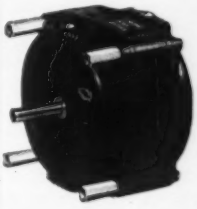
AWARD-WINNING **TEMPERATURE RECORDER**

uses a

BODINE MOTOR

The new Wheelco Deflection-Type Temperature Recorder was recently judged one of the five outstanding designs of the year in the Eleventh Annual Product Design Competition conducted by *Electrical Manufacturing Magazine*.





A Bodine Type K motor positions the follow-up arm and pen. This motor was selected because of its precise, reliable operation and rugged construction.

The Type K motor is especially designed for use on instruments and controls. Write for complete information. Bodine Electric Company, 2244 W. Ohio Street, Chicago 12, Illinois.

BODINE

FRACTIONAL HORSEPOWER **MOTORS**

—MICO—

2 & 3-DIMENSIONAL ENGRAVER

FEATURES

1. Ball Bearing Micrometer spindle for absolute control of depth of cutter in all four ratios.
2. Accuracy of reproduction in four ratios due to excellent precision machining of pantograph arms.
3. Absolute accuracy in three-dimensional duplicating.
4. Many attachments available to increase versatility, such as extension arm, rapid self-centering vise, extension post for pantograph and copy carrier, hand engraving spindle and many more.
5. Copy and work right-side up and in view of operator.

Catalog on Request

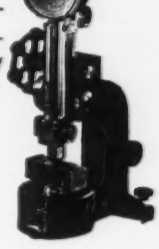
MICO INSTRUMENT CO.

86A Trowbridge St. Cambridge 38, Mass.

HARDNESS TESTING...

done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 42 years.

In general use for specification purposes. Simple, sturdy. Comparatively inexpensive.

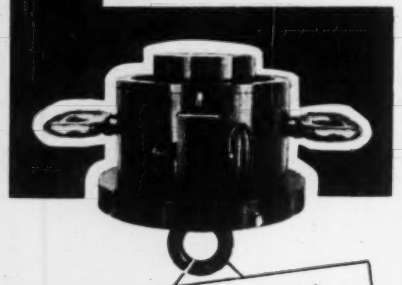


Illustrated bulletins free

The Shore Instrument & Mfg. Co., Inc.

9025 Van Wyck Ave., Jamaica 2, N. Y.

now you can assemble your own



Force Measuring systems

for use in applications such as dynamometers, industrial weighing, strength of structures, jet engine thrust, and countless other force-measuring problems. Illustrated is the famous Emery Hydraulic Cell, basic unit of Emery hydraulic testing and force-measuring systems.

All components are simply constructed, but rugged; they are compact in size, extremely sensitive and accurate. Easy to mount and use. Send for complete literature and prices; also our engineers will be pleased to discuss your force-measurement problems and make recommendations.

a complete line of hydraulic components: load cells for compression and tension; load indicators; strip and circular chart recorders; hydraulic jacks, valves, tools, and other special devices.

THE A.H.EMERY CO. · HYDRAULIC WEIGHING · 75 YEARS

THE A. H. EMERY CO. STAMFORD, CONN.

Physicist wanted — For design and development of electronic and mechanical instrumentation equipment used in the pursuit of flight research work. Several years of theoretical and practical experience necessary. Salary commensurate with qualifications. Permanent position. Give details in first letter. Cornell Aeronautical Laboratory, Inc., 4455 Genesee Street, Buffalo 21, New York.

Wanted: Instrument Personnel

Draftsman — Designers — Project Engineers. Experience: Aircraft or Industrial Pressure Instruments, Gyroscopes, Flight Test Instrumentation, and Controlling Switches. California location. Answer full details. Box 173, Instruments Publishing Co., Pittsburgh 12, Penna.

MACDONALD ELECTRONIC MICROAMMETER

THIS instrument is designed to replace high-sensitivity galvanometers in many applications. Due to its ruggedness, freedom from burnout, and relative insensitivity to shock, it is an ideal instrument for use in balancing resistance bridges, measuring crystal rectifier output, photocell, strain-gage, thermocouple, and lead-sulphide cell currents, etc. The instrument may also be used as a D.C. pre-amplifier for recorders. When used in this manner, current amplification of 1,000 is available.

SPECIFICATIONS:

Sensitivity •
1 microampere full scale
50 microvolts full scale

Ranges •
1, 3, 10, 30, 100 microamperes

Permissible overload —
¼ ampere

Accuracy — ±3% full scale

Time constant — about 6 seconds

Power supply — 110 — 125 V, 60 C.P.S.

Dimensions — 7" x 8" x 9½"

PRICE — $225.00 F.O.B. CAMBRIDGE, MASS.

W. S. MACDONALD CO., INC. 55 UNIVERSITY ROAD CAMBRIDGE 38, MASSACHUSETTS

Development and Application Engineer

Experienced in designing, building, and field application of specialized electrical and mechanical instruments and test equipment. Opportunity to introduce, develop and apply new test equipment in utilities, industrials and railroads. Well-established, medium-size company. Location East. Box 174, Instruments Publishing Co., 921 Ridge Avenue, Pittsburgh 12, Penna.

Leather Cases
Milsco offers you quantity production of fine leather cases for all types of instruments. We are completely equipped for a wide variety of manufacturing operations including buckles, stampings, and other metal parts. Add extra utility, value to your instruments with Milsco leather cases. Quotations promptly submitted
MILSCO MFG. COMPANY
2748 N. 33RD STREET, MILWAUKEE 10, WIS
25th YEAR
Milsco

JOURNAL of the Instrument Society of America

I.S.A. National Office, 921 Ridge Ave., Pittsburgh 12, Penna.

Vol. 6 JANUARY 1950 No. 1

An Open Letter to Members

Dear ISA Member:

The 1949 operations of your Society have lacked spectacular features, nevertheless we believe that progress has been made.

The addition of 316 new members to our rolls since April 1949 is proof of the growth of instrumentation in science and industry and is strong evidence that ISA membership is considered a virtual necessity by instrument men.

Total membership now is 4,224. The number of Sections has increased from 45 to 49 since that date: Wilmington, Delaware being the latest to receive a charter.

The 42 papers presented at the St. Louis Conference in September set a new record for ISA meetings. The St. Louis Exhibit also set a record for products exhibited.

The 1950 meeting is planned for the Memorial Auditorium, Buffalo, September 18th to 22nd. The location of this meeting will permit the attendance of many members who have heretofore not attended a meeting.

The social function at St. Louis, the River Excursion on the Steamer Admiral, also set a record for attendance and good fellowship.

The list of sections and their membership is as follows: Akron 44, Albuquerque 43, Aruba 63, Atlanta 17, Baltimore 78, Boston 95, California 166, Central Illinois 34, Central Indiana 82, Charleston 83, Chicago 323, China Lake 89, Cincinnati 69, Cleveland 135, Columbus 28, Cumberland 15, Detroit 72, Eastern New York 105, Gulf Coast 45, Houston 120, Kansas City 58, Louisville 40, Montreal 73, New Jersey 232, New Orleans 6, New York 221, Niagara Frontier 91, North Texas 44, Northern California 91, Northern Indiana 24, Oak Ridge 67, Ontario 44, Philadelphia 360, Pittsburgh 224, Presque Isle 23, Richland 102, Rochester 70, Sarnia 82, South Bend 12, South Michigan 33, South Texas 45, St. Louis 141, Tennessee 47, Tulsa 92, Twin Cities 45, Washington 129, Wayne County 35, Wilmington 33, Members at large 34.

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio.
Fourth Tuesday, Meeting at 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
L. J. Paddison, 911 Parkland Circle, Albuquerque, N. M.

ARUBA
K. H. Walker, P. O. Box 389, c/o Lago Oil & Tranpsort Co., Ltd., Aruba, N.W.I.
First Tuesday, Meeting at 7:15 P. M.

ATLANTA
H. Kockritz, Fischer & Porter Co., 84 Peachtree St., Atlanta, Ga.
Fourth Monday, Meeting at 7:45 P. M.

BALTIMORE
George B. Greer, 631 E. 36th St., Baltimore 18, Md.
Second Friday.

BATON ROUGE
Jack L. Pillow, 801 Lake Park Drive, Baton Rouge, La.

BOSTON
C. J. Nazzaro, 456 Central Avenue, Milton 87, Mass.
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., Patten's Restaurant.

CALIFORNIA
D. D. Taylor, 1955 Mendocino Lane, Altedena, Calif.
First Tuesday, Dinner at 6:30 P. M. Meeting at 8:00 P. M.

CENTRAL ILLINOIS
H. F. Lange, 2101 W. Glen Avenue, Peoria 5, Ill.
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
H. F. Coffey, 4029 N. Temple Ave., Indianapolis, Ind.
First Tuesday, Meeting at 7:30 P. M.

CHARLESTON
S. E. Mitchell, 312 24th St., Dunbar, W. Va.
First Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Kanawha Hotel.
February 6, "What Makes an Instrument a Good Instrument?", R. E. Clarridge, Taylor Instrument Cos.

CHICAGO
Lloyd E. Ertsman, Rm. 1420 Fisher Bldg., 343 S. Dearborn St., Chicago, Ill.
Third Tuesday, Dinner at 6:45 P. M., Meeting at 8:00 P.M., W.S.E. Auditorium.
January 17, Western Society of Engineers (84 E. Randolph St.), "Automatic Control and the High Speed Analog," G. A. Philbrick, G. A. Philbrick Researches, Inc.
February 7, "Flow Meter Installation Troubles," J. B. McMahon and W. L. Eckdahl.

CHINA LAKE
A. G. DeBell, U. S. Naval Ordnance Test Sta., China Lake, Calif.

CINCINNATI
Edward H. Muhleisen, 320 Durrell Ave., Cincinnati 15, Ohio
First Monday, Meeting at 8:00 P.M., Eng'r. Society Hqs.

CLEVELAND
R. M. Woodside, 332 Oakmoor Rd., Bay Village, Ohio
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society.

COLUMBUS
Orval Linebrink, c/o Battelle Memorial Institute, 505 King Ave., Columbus, Ohio
Third Thursday, Battelle Auditorium.

CUMBERLAND
Clyde Babst, 225 Cecilia St., Cumberland, Md.
Tuesday after Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Algonquin Hotel.

DETROIT
Seymour Sterling, 13331 Linwood, Detroit, Mich.
Second Wednesday, Meeting at 8:00 P.M., Rackham Bldg.

EASTERN NEW YORK
W. R. McKegg, c/o General Engineering & Consulting Lab., General Electric Company, Schenectady, N. Y.
First Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M.

GULF COAST
W. N. Sloan, 2558 Tyrrell Parkway, Port Arthur, Texas.
Third Tuesday, Meeting at 7:30 P.M., Lamar College.

HOUSTON
E. E. Kleir, c/o The Foxboro Co., 2518 S. Blvd., Houston 6, Texas
Last Monday, Meeting at 8:00 P.M., Engineers Club.
January 30, "Improvised Instrumentation," R. L. Nichols, Magnolia Petroleum Co.
February 27, "The Manufacture of Starch for Food and Industry," T. H. Pierson, Corn Products Refining Co.
March 27, Banquet and Installation of New Officers.

KANSAS CITY
Lewell F. Spies, c/o J. F. Pritchard & Co., 908 Grand Ave., Kansas City, Mo.
First Tuesday, Meeting at 7:30 P. M.
February 7, "pH Control and Its Applications," Dr. A. O. Beckman.
March 7, "Refinery or Chemical Process Control," Hart Fisher, Monsanto Chemical Co.

LOUISVILLE
H. C. Scherffius, 980 Palatka Rd., Louisville 8, Ky.
Fourth Tuesday, Meeting at 8:00 P.M.

MONTREAL
L. J. Mizuhara, Monsanto (Canada) Ltd., 425 St. Patrick St., Ville LaSalle, Quebec, Canada
Last Monday, Meeting at 8:00 P.M.

NEW JERSEY
W. D. Archibald, 605 Westminster Ave., Elizabeth 3, N. J.
First Tuesday, Dinner at 6:00 P. M. Meeting at 8:00 P.M., Essex House.

NEW ORLEANS
W. H. Haney, 2927 Music Avenue, New Orleans, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
Norman J. Cherry, P. O. Box 608, Merrick, L. I., N. Y.
Last Monday, Meeting at 7:30 P.M., Statler Hotel.
January 27-28, January Conference at Statler Hotel, "Temperature Measurements", Theory, Practical Instrument Application and Maintenance Problems, Banquet on Friday Evening.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 9, N. Y.
Fourth Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Institute of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9, Texas

NORTHERN CALIFORNIA
M. A. Dimmick, 5607 Alta Punta, El Cerrito, Calif.
Third Monday, Meeting at 7:30 P.M.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill.
Third Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Gary Y.M.C.A.
February 7, Joint Meeting with The Chicago Section.

OAK RIDGE
John H. Clark, 138 Clayton Hall, Oakridge, Tenn.
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M., Oak Terrace.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada
Third Thursday, Dinner at 6:45 P. M. Meeting at 8:15 P. M.

PHILADELPHIA
C. W. Wood, 6908 Market St., Upper Darby, Pa.
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.
January 18, "New and Interesting Developments in Television."

PITTSBURGH
Miss Louise Suckfield, P.O. Box 2038, Pittsburgh 30, Pa.
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Roosevelt Hotel.
January 23, "Stump the Experts." A Main-

Continued on page 76

Dynamic Accuracy In Temperature Measurement*

By J. G. ZIEGLER and N. B. NICHOLS†

THE dynamic performance of a temperature measuring element is concerned with its behavior under changing or *dynamic* conditions as contrasted with the static performance under constant conditions. The usual accuracy specifications are limited to the static accuracy since it is relatively easy to define the static test conditions and to reproduce these test conditions whenever necessary. The dynamic accuracy is often partially described by giving the speed of response for some given set of dynamic test conditions, but more generally, little attention is paid these characteristics of the measuring element. An instrument accurate to a fraction of a degree under static conditions can easily be in error by a great many degrees when the temperature is changing.

The inability of thermometric elements to accurately follow changing temperature not only produces errors in measurement; it often has a profound effect on the results obtainable when the temperature is automatically controlled. In certain control applications, elimination of measurement "lag" would remove such a large proportion of the effective control circuit lag that temperature deviations could be practically eliminated. An example of such a process is shown in Fig. 1; a steam heated surface raising an air stream to a controlled temperature. A sudden change in the temperature or flow of incoming air would cause a temperature deviation and recovery as shown by the dotted line. The actual chart record would not be as alarming due to the presence of measurement lag as shown by the solid line, but the dotted record of air temperature would be shown by a measuring element with perfect dynamic characteristics installed beside the imperfect element of the controller. If the controller were actuated by the perfect measuring element and properly adjusted for the easier task which it would then have, a similar change in load would be corrected very quickly and with almost no temperature deviation.

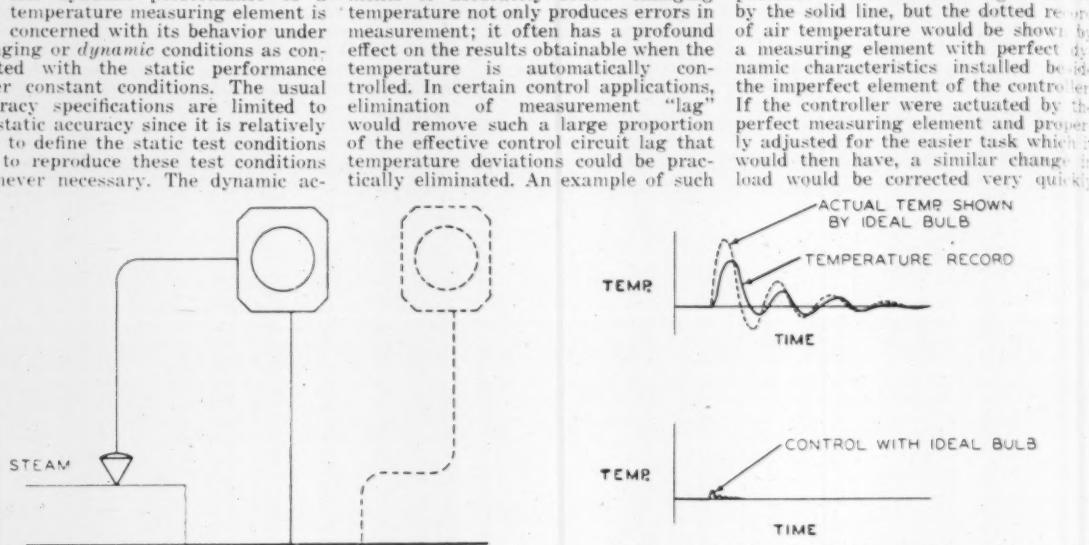


Fig. 1. Air heater system and response curves. This process is an example of a control system where measurement "lag" elimination achieves good control.

All practical temperature measuring elements are imperfect dynamically simply because some heat is required to change their temperature and there is only a finite surface area through which the heat can flow. Consider the temperature measuring element of Fig. 2 having two important characteristics, a heat capacity of 0.004 BTU per °F and a surface area of 0.024 square feet. If this element be immersed in a fluid flowing at such a velocity past the surface that the coefficient of heat transfer

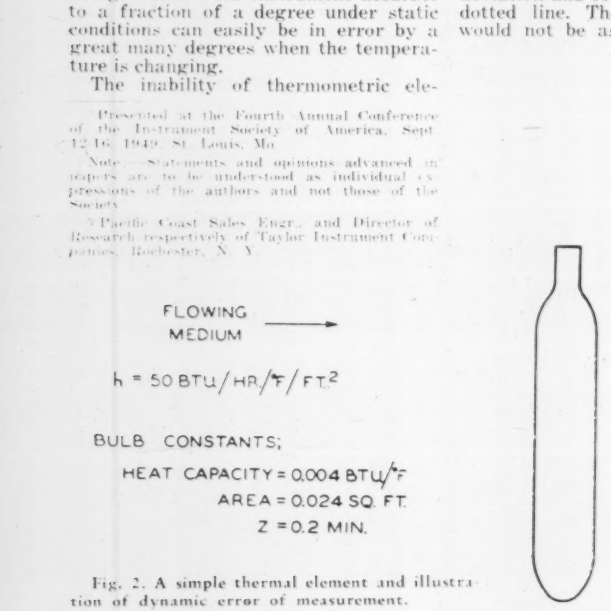
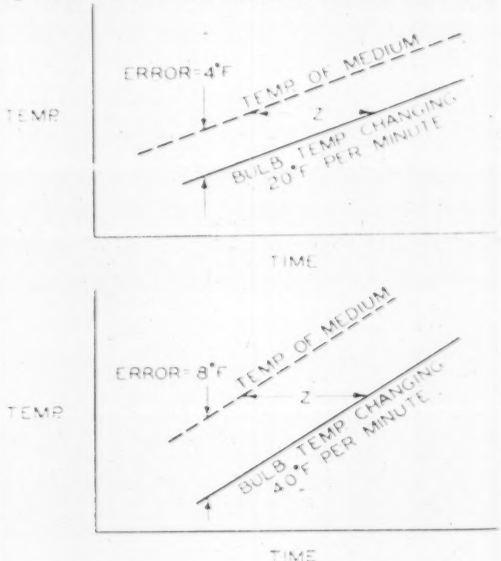


Fig. 2. A simple thermal element and illustration of dynamic error of measurement.



*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

Note—Statements and opinions advanced in papers are to be understood as individual expressions of the authors and not those of the Society.

†Pacific Coast Sales Engr., and Director of Research, respectively, of Taylor Instrument Companies, Rochester, N. Y.

50 BTU/hr./°F./ft.² the dynamic characteristics of the system may be established. If the temperature reading is increasing at the rate of 20° per minute, as shown in Fig. 2, a certain amount of heat must be flowing into the element.

$q = (20)(60)(0.004) = 4.8$ BTU/hr.

All of this heat must flow through the fluid film surrounding the bulb and, since the rate of heat flow is constant for a given rate of temperature change, the temperature drop over the film may be calculated from the conventional steady state heat transfer equation.

$$q = h\,A\,\Delta T$$

$$\Delta T = \frac{q}{(h)(A)} = \frac{4.8}{(50)(0.024)} = 4°\text{F.}$$

Thus, in order to keep the element temperature rising at a rate of 20° per minute, the medium temperature must remain 4°F higher. Thus in this example, the dynamic error of measurement is 4°F. Under similar conditions, since the rate of heat flow is proportional to the temperature difference, an 8°F. drop would be required to cause the element to change twice as fast or 40° per minute. The dynamic error then varies with the rate of temperature change of a thermometric element so it is generally more convenient to express the dynamic characteristics of a given element in a given medium as a ratio of the dynamic error to the rate of temperature change. This ratio Z has the dimensions of time and is called "Bulb Lag" which in the example of Fig. 2 is equal to:

$$Z = \frac{\text{(dynamic error)}}{\text{(rate of temp. chg.)}} = \frac{4}{20} = \frac{8}{40} = 0.2 \text{ min.}$$

The meaning of this quantity is shown on Fig. 2 and is the time by which the thermometer reading lags the true temperature when both are changing at constant rate. A better interpretation is that the dynamic error would be reduced to zero in a time equal to Z provided the bulb temperature kept changing at the same rate). This is shown on Fig. 3 for two cases. In the first, the bulb is subjected to a sudden increase in temperature and responds on a curve of constantly decreasing slope. But at any instant, it is changing at a rate proportional to the remaining temperature difference so it would reduce the error to zero in the same length of time if it continued at its instantaneous slope. In the second case, the true temperature (potential) is assumed to change from one value to another at a constant rate. Note that the bulb reading approaches a limiting maximum slope equal to that of the potential. At every instant, the reading is changing at a rate that would reduce the error to zero in a time equal to Z.

In terms of the bulb heat capacity C and its area A and the coefficient of heat transfer "h" the bulb lag "Z" is equal to:

$$Z = \frac{C}{(A)(h)}$$

This equation indicates some of the possibilities for reducing bulb lag. Any increase in the coefficient of heat transfer effects a corresponding decrease in bulb lag. This indicates that bulbs should always be located at a point where the velocity of fluid is high since "h" increases approximately as the square root of velocity. A little care in this respect can have a very marked effect on bulb lag and on temperature control obtainable. By the same token, the coefficient of heat transfer is much greater in agitated liquids than in gases or even vapors at low velocity, so if a choice exists, the better medium should surround the bulb. Examples of this exist in fractionating columns, evaporators, etc. The vapor leaving a boiling liquid will be at the temperature of the liquid so it should be much better to install a bulb in the liquid on a column plate than in the vapor space between plates. In the case of an evaporator in which the liquid has a boiling point rise, the vapor will be superheated and consequently a gas film would surround a bulb located in the vapor space. The bulb should be located in the liquid. Even in saturated vapors, bulb location should be checked carefully to be sure that it is not in a pocket where fixed gases can collect.

Another possibility of reducing bulb lag is to change the bulb itself, so as to reduce its heat capacity or increase the area, that is, reduce the value of C/A. The most common method is to reduce the bulb diameter, going to the so-called "capillary bulbs" in tube system instruments or to bare thermocouples or resistance thermometers made of the smallest diameter wire which will stand the mechanical strain or the erosive and corrosive conditions encountered in the application. Occasionally finned bulbs are used, although the improvement that can be effected is limited. In general, for bare bulbs or thermocouples, without a protecting well, the internal resistance of the bulb is negligible compared to the fluid film resistance on the outside and the bulb can be considered homogeneous. Actually, there is a slight resistance to heat flow through the metal of the bulb which adds a fraction of a second to the lag caused by the fluid film, but the latter is much larger, varying from a second or two up to several minutes. This is not the case for thermometric elements installed in protective wells unless exceptionally good thermal contact exists between the sensitive element and the well since an air space of a few ten thousandths of an inch between the two can add many seconds to the overall bulb lag. In addition, a more complex "two capacity" lag results which will be considered later after another method of reducing the lag of bare bulbs is explored.

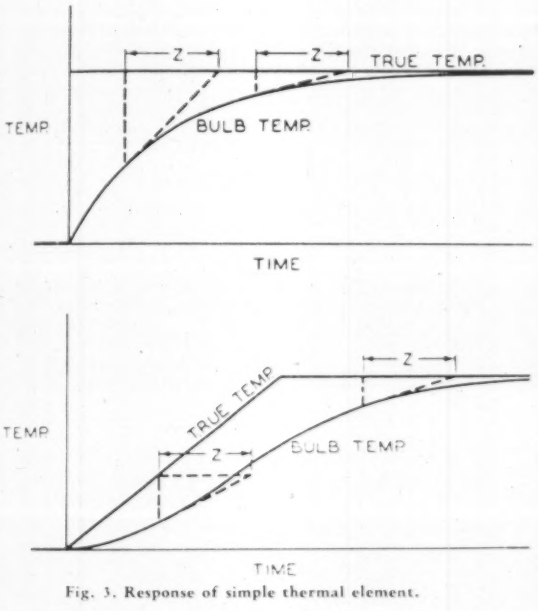


Fig. 3. Response of simple thermal element.

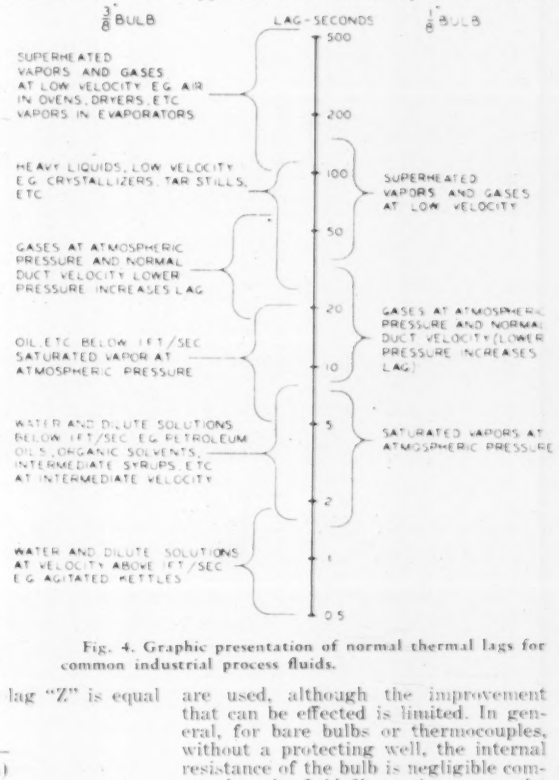

3/8" BULB
LAG - SECONDS
1/8" BULB
500
200
100
50
20
10
5
2
1
0.5
SUPERHEATED VAPORS AND GASES AT LOW VELOCITY E.G. AIR IN OVENS, DRYERS, ETC. VAPORS IN EVAPORATORS
HEAVY LIQUIDS, LOW VELOCITY E.G. CRYSTALLIZERS, TAR STILLS, ETC.
SUPERHEATED VAPORS AND GASES AT LOW VELOCITY
GASES AT ATMOSPHERIC PRESSURE AND NORMAL DUCT VELOCITY. LOWER PRESSURE INCREASES LAG
GASES AT ATMOSPHERIC PRESSURE AND NORMAL DUCT VELOCITY (LOWER PRESSURE INCREASES LAG)
OIL, ETC. BELOW 1 FT./SEC. SATURATED VAPOR AT ATMOSPHERIC PRESSURE
WATER AND DILUTE SOLUTIONS BELOW 1 FT/SEC. E.G. PETROLEUM OILS, ORGANIC SOLVENTS, INTERMEDIATE SYRUPS, ETC. AT INTERMEDIATE VELOCITY
SATURATED VAPORS AT ATMOSPHERIC PRESSURE
WATER AND DILUTE SOLUTIONS AT VELOCITY ABOVE 1 FT./SEC. E.G. AGITATED KETTLES

Fig. 4. Graphic presentation of normal thermal lags for common industrial process fluids.

Derivative Compensation for Thermal Lag

Even with good installation practice and the use of bulbs with low C/A values, the lag is often larger than can

be tolerated; measurement of transient changes cannot be made with accuracy or control results are miserable. In Fig. 4, approximate values of normal bulb lags are given for a variety of conditions for bulbs $\frac{3}{8}$" and $\frac{1}{8}$" in diameter. These values are not limited to tube system type thermal elements; they apply equally well to a bare thermocouple $\frac{1}{8}$" in diameter or to a thermocouple *welded* into a $\frac{3}{8}$" tube since the C/A values will be essentially the same. The values would not apply to resistance thermometers in protective tubes because high thermal conductivity can-

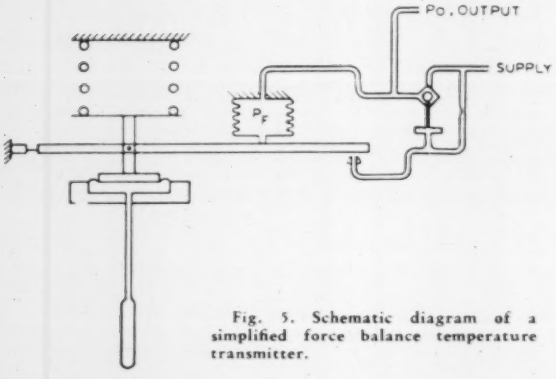


Fig. 5. Schematic diagram of a simplified force balance temperature transmitter.

not be obtained without electrical contact.

Reference to the table shows that bulb lags are not inconsiderable in most cases. The possibility of using small diameter bulbs is generally limited to installation in non-corrosive and non-erosive gases and vapors; even $\frac{3}{8}$" diameter bulbs are often too frail to stand the mechanical stresses encountered in flowing streams of viscous liquids. Any increase in wall thickness or contact with supporting members increases the lag by increasing the capacity or impeding free circulation about the bulb. In view of the rather obvious requirements for faster speed of response it seems desirable to point out another way of improving the dynamic accuracy of thermal systems.

As in most compensation problems, the method is quite simple. A quantity proportional to the error is measured or sensed and a correction is applied to the reading so that the final result is the sum of the uncorrected reading and the correction. In this case, the error is the temperature difference between the sensitive element and the temperature of the medium and is equal to:

$$\Delta T = \frac{(dT)}{(d\theta)} \bullet \frac{(C)}{(A)} \bullet \frac{1}{h} = \frac{(dT)}{(d\theta)} \bullet Z$$

Since the error is proportional to the rate of change of bulb temperature,

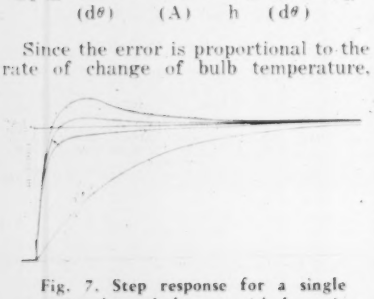


Fig. 7. Step response for a single capacity thermal element with dynamic compensation.

$dT/d\theta$, one merely needs to measure this rate of change, multiply by the appropriate bulb lag and add this correction to the bulb temperature to obtain the corrected or true temperature. The pneumatic transmitter offers an easy solution to this problem. Consider the simplified circuit of a force balance pneumatic transmitter as shown in Fig. 5. A gas filled tube system has its bulb immersed in the process medium. The force resulting from the gas pressure on the diaphragm is balanced by the biasing spring and the force from the balancing bellows. An increase in bulb temperature for example will move the baffle away from the nozzle, decreasing the nozzle back pressure and increasing the relay valve output pressure. This increase in output pressure, flowing into the balancing bellows, applies an opposing force to the diaphragm of sufficient magnitude to substantially prevent movement of the diaphragm and baffle. The change in balancing bellows pressure is then directly proportional to the change in the bulb pressure which is in turn, proportional to its temperature. By suitable calibration, a balancing bellows pressure change of say, 3 to 15 psi can be made to correspond to the desired temperature span of the transmitter. The output pressure is then transmitted to a suitable pressure receiver also having a pressure span of 3 to 15 psi. Ambient temperature and barometric pressure compensation would, of course, be required in any complete instrument, although they are not shown.

Returning to the derivative compensation for thermal lag or "dynamic compensation," we note that the rate of pressure rise in the balancing bellows is directly proportional to the rate of temperature rise of the gas-filled bulb. Increasing pressure in the balancing bellows will require the flow of air into the bellows. In fact, the rate of flow of air into the bellows is directly proportional to the rate of pressure rise in it. Introducing a capillary or needle valve restriction in the line to the balancing bellows will result in a pressure drop which is proportional to the air flow and thus proportional to the rate of

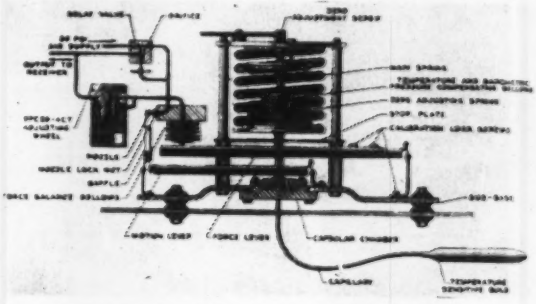


Fig 6. Schematic diagram of a temperature transmitter with dynamic conpensation for measurement "lag."

temperature rise of the bulb. The output pressure of the relay valve will thus be equal to the balancing bellows pressure plus this pressure drop. Suitable adjustment of the restriction allows selection of the appropriate lag correction factor to neutralize the dynamic error. The adjustment dial on the restriction can, in fact, be calibrated directly in terms of the time lead (or dynamic compensation factor) introduced by it.

Design and Operation of Temperature Transmitter with Dynamic Compensation

The principal involved in this instrument is quite simple. Fig. 6 shows a schematic diagram of a temperature transmitter utilizing this principal. The dynamic compensation or "Speedact" response is obtained by means of a needle valve in the line between the

[1] Taylor "Transaire" Temperature Transmitter with "Speedact"

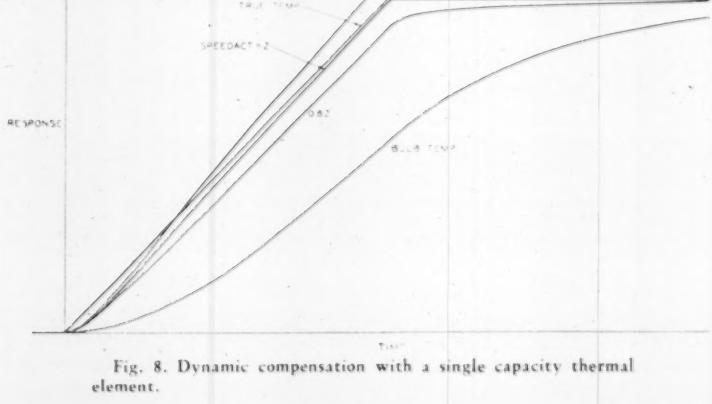


Fig. 8. Dynamic compensation with a single capacity thermal element.

relay output (which goes to the receiver) and the balancing bellows. The needle valve unit incorporates a free bellows with one side connected to output and the other to the balancing bellows. This construction results in stable pneumatic operation as the needle valve is adjusted from wide open to the closed off position. The lead time (lag compensation or "Speedact" time) dial is directly calibrated from 2 to 200 sec. The performance which can be obtained when the thermal system can be regarded as a single capacity thermal element is shown in Figs. 7 and 8. The time scale

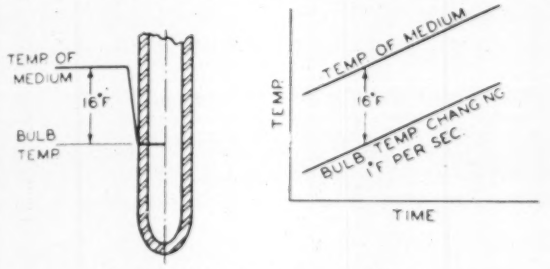


Fig. 9. Single capacity thermal element.

is expressed in terms of the bulb time constant (Z), as previously described.

Such a transmitter makes possible temperature measurement not previously obtainable since it produces a much faster response to temperature changes in mediums normally giving excessive measuring lag, such as oils, viscous liquids, vapors and gases. Used for measuring air temperature and humidity in conditioned spaces it shows variations that were previously unsuspected because they were not observable on

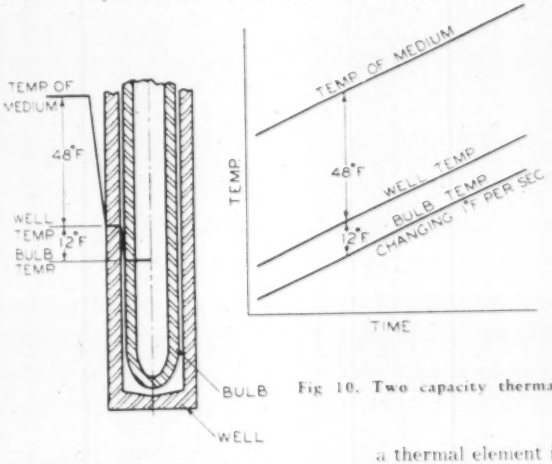


Fig 10. Two capacity thermal element.

conventional measuring devices. In the laboratory, it has shown the true course of temperature during a few second test for thermal death rate of bacteria. When the bulb is placed in an air stream at a higher temperature, the reading quickly moves to the true temperature, (Fig. 7), although many seconds later the bulb temperature is still well below that of the air.

Adjustment of the instrument for the particular application lag can be made in a number of ways. Generally, the lag can be estimated from tables with sufficient accuracy. Figs. 7 and 8 show the effect of insufficient or excessive setting of the "Speedact" response. Note that insufficient "Speedact" gives something less than complete compensation for bulb lag and that excessive settings show greater deviations than actually occur although in either case, the readings are nearer the true value than those which would be indicated by the bulb.

Precise "Speedact" setting can be easily made if known changes in temperature can be effected. For example, if the bulb can be removed from its position in the process where the temperature is known and heated or cooled to a different temperature and then returned to the process, the "Speedact" adjustment may be quickly turned until the receiving instrument indicates the true temperature. If the exact medium temperature is not known, the same test can be made and the adjustment turned until the receiver reading or the output of the transmitter is stationary; if the bulb temperature is rising and an excessive setting is made, the reading will decrease and vice versa.

Two Capacity Thermal Element

As mentioned earlier, the response of a thermal element installed in a protective well is more complex than that of a simple bare bulb. If infinitely good thermal contact existed between the bulb and its covering, the only increase in lag would be that caused by the increase in the heat capacity per unit outside area. This can be achieved if the covering is plated on the bulb, or if a sheath is soldered to the bulb. In the usual arrangement in which the bulb or thermocouple is made removable from the well, a definite resistance to heat flow between bulb and well is produced by the air space between the two and the limited contacting surface. This resistance can be decreased if the air space is filled with mercury or a thin crimped metallic sheet[2] which makes good contact with both the well and the bulb. However, even this construction adds several seconds to the lag.

The comparison between the two systems is shown in Figs. 9 and 10, depicting the temperature gradient between medium and bulb during a uniform rate of temperature rise of 1° per second. In the case of $\frac{3}{8}$" bare bulb, the entire temperature drop of 16°F. is in the film surrounding the bulb. Adding $\frac{5}{8}$" O.D. well to the bulb increases the ratio of C/A by 200% so the drop through the fluid film for the same rate of temperature rise would be 48°F. In addition,

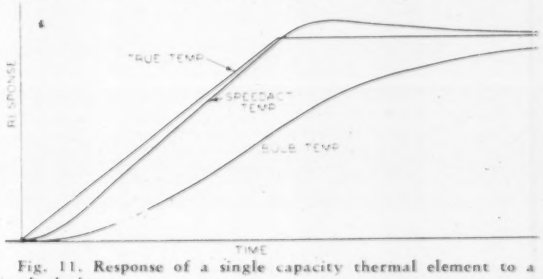


Fig. 11. Response of a single capacity thermal element to a gradual change.

there is a 12°F. drop across the resistance between well and bulb making a total temperature drop of 60°F. from medium to bulb. This indicates a total lag of 60 seconds, since a rate of temperature change of 1°F. per second was assumed.

The response of the bulb and well combination to gradual and step changes in temperature are shown in Figs. 11 and 12. Notice that the typical two capacity S shaped curve is apparent in Fig. 12. When dynamic compen-

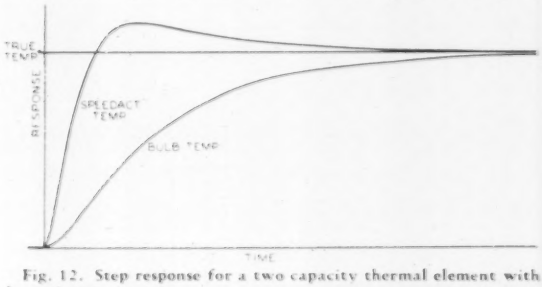


Fig. 12. Step response for a two capacity thermal element with dynamic compensation.

sation is applied, to this system, it is not possible to set the "Speedact" to achieve as exact a compensation for the lag of both bulb and well as it was with the simple bulb. Best results are achieved if the "Speedact" is set equal to the total lag (60 seconds in the example). The transmitter output is shown for this setting in both Fig. 11 and Fig. 12. Note the delay in reaching the true temperature in Fig. 12 and the small overpeak which results. In normal work this overpeak is generally inconsequential.

Conclusion

It is believed that the use of a derivative transmitter to compensate for the inevitable lag of thermal elements offers a valuable and unique tool in the field of temperature measurement and control making possible a degree of speed and accuracy not previously obtainable.

[2] Taylor "Thermospeed" sleeve for bulb and well construction.

Long Range Multi Channel Telemetering System*

By JOHN T. MENGEL†

Introduction

THE Naval Research Laboratory, in conjunction with its upper atmosphere research program, has developed a telemetering system for recording 30 channels of data originating in a missile over a distance as great as 500 miles. This system, the second such system put in operation at White Sands by the Naval Research Laboratory, is called the "Matrix Telemetering System," and has the following characteristics:

(a) Pulse time modulation of an r.f. carrier is used.
(b) 30 input channels.
(c) 312.5 samples per second per channel.

Fig. 1. AN/DKT-2 (XN-1) Telemeter Transmitting Set

Fig. 2. Matrix System Ground Station

(d) 0 to +5 volts channel input voltage.
(e) .118 megohm input resistance.
(f) Six point voltage calibration on each channel every 10 seconds.
(g) An overall accuracy of at least ±1%.
(h) Cross talk between channels less than ¼%.
(i) Average output power in the r.f. pulse of about 4 kw.

The Telemeter Transmitter Set for the Matrix System is designated the AN/DKT-2, and is manufactured for the Naval Research Laboratory by the Hazeltine Electronics Corporation. All ground station equipment was made at the Naval Research Laboratory, and has been operated at White Sands under the technical direction of the Naval Research Laboratory field group there.

General Description

The matrix telemetering system utilizes pulse time modulation to convey thirty channels of input information. Data in the form of varying d.c. voltages is supplied to the equipment from the various experiments. The data channels are sampled successively and the whole process is repeated at a 312.5 cycle rate. A coded triple pulse identifies the start of each group and establishes a time reference framework, or matrix, of 32 intervals of 100 usec. each. Within 30 of these intervals, single data pulses occur, the position of the pulse within its interval indicating the voltage being measured on the channel. This chain of pulses is used to modulate an r.f. transmitter operating at a frequency of 1025 megacycles per second with an average power in the pulse of about 4 kw.

The ground station receives the recurrent train of pulses from the remote transmitter in a suitable receiver. The triple pulse is recognized by a discriminator and is used to generate a matrix in exact phase with the matrix in the transmitter. From this, signals are obtained at any particular time in the matrix which are used to generate the sweep voltages for the cathode ray tubes on which the data is presented as intensity modulation. Pulses generated at the beginning of each matrix interval are also applied to the display, and the scopes are photographed on a continuous film camera. There results a graph of the variation of the input voltage with time, with reference lines (which do not vary in position) between each of the data lines.

Each ground display has six cathode ray tubes upon which the thirty data channels can be applied in any combination. Sweeps of appropriate duration and timing in respect to the triple pulse are so arranged that one tube after another is swept in succession until all channels are recorded. Additional information is also supplied on the record by the application of signals to the cathode ray tube to indicate time from a standard source. The system is calibrated by periodic application of a series of voltages to each channel in turn in the airborne set.

The airborne transmitter is made in two units: the transmitter unit, and a battery box. The ground stations consist of four standard size relay racks, the first of which contains the power control panel, receiver, monitor oscilloscope, synchronization pulse discriminator, matrix oscillator, scale of 32 counter and time base generators, and power supplies. The other three racks are identical, containing the recording cameras and film magazines, recording cathode ray tubes, sweep generators, video amplifiers and power supplies. Two complete ground stations are utilized per flight, with a galvanometer recorder used in conjunction with them for recording field strength of each station, plus that of a remote station, as a function of flight time.

The overall functioning of the matrix telemetering system may be understood in relation to the major components of the equipment by reference to the block diagrams for the airborne station and the ground station, respectively. The block diagram for the airborne station shows the 10 kc. oscillator to be the initiating independent part of the circuit. The sine wave output of this oscillator is fed to a multivibrator which serves to shape it to derive a series of pulses 100 usec. apart from it. These pulses are fed through a cathode follower to a bus feeding each of the 32 tubes of the electronic commutator. These tubes are arranged as a chain so connected that only one tube can conduct at a time. As any of these thyratron tubes fires, it readies the next tube in the chain. Upon the appearance of the next pulse on the triggering bus, conduction shifts to the next succeeding tube, and so on down through the whole chain of thirty-two tubes, and the process is repeated when the last tube readies the first tube for conduction. As each of the first 30 of the chain tubes fires in turn, it generates a saw-tooth wave form which is added electrically to the input voltages for the channels. When the sum of these two voltages reaches a predetermined level (as it will sometime during the 100 usec. interval) it will cause its corresponding pick off thyratron to fire, producing a time modulated output pulse. The greater the input voltage, the sooner the sum of the input voltage and sawtooth will reach the critical voltage. The output pulses from the various channels are

*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

†Naval Research Laboratory, Washington 25, D. C.

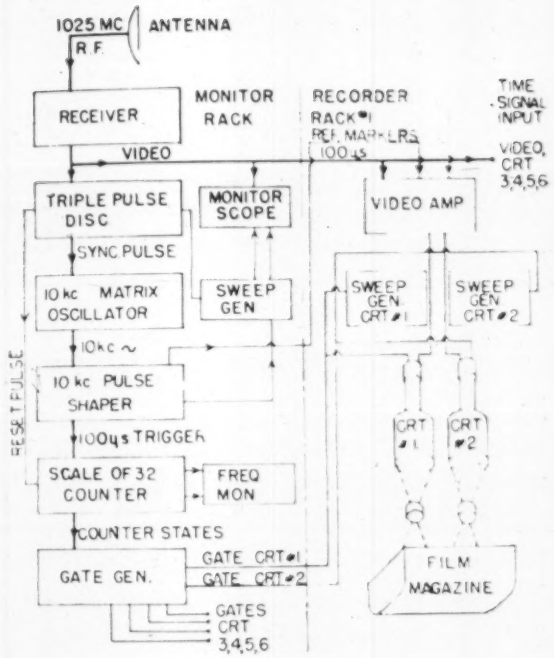


Fig. 3. Block Diagram, Matrix System Ground Station

collected on a common bus and used to modulate the transmitting tube. Also used to moduate the transmitter is the triple pulse generated at the time of the firing of the thirty second chain tube.

Each ground station comprises four racks of two main type of units. The Monitor rack contains receiving and decoding apparatus as well as a monitoring oscilloscope. Three recording racks, all identical, are used with each ground station.

Referring to the block diagram for the monitor rack, it should be noted that heavy outlines and signal lines indicate the main units and signal paths. The receiver delivers the video signal on two lines — to the recording racks and into the synchronizing pulse discriminator where the triple pulse is recognized and supplies a pulse which is used to phase and frequency lock the 10 kc matrix oscillator to the airborne oscillator. The output of the oscillator is shaped and fed into the scale-of-32 counter. This counter operates in synchronism with the chain counter in the airborne unit. It is reset by the synchronizing pulse, when necessary, so that particular states correspond in both units. By means of resistor networks from different stages of the counter, the state selector delivers a timed series of 100 usec. long pulses to a patchboard on the panel of the unit. Suitable connections are made to the trigger and gate unit to form gates for controlling the sweep circuits in the recorder racks.

There are several auxiliary units in the monitor rack. The frequency monitor determines whether the matrix oscillator is operating on the proper harmonic of the 312.5 cycle synchronizing signal, and indicates the proper frequency by means of lights on the face of the unit. The monitor oscilloscope is used for adjustment of the units and for monitoring the signal during operation. It is swept from associated generators which are synchronized from 312.5 cycle and 10 kc pulse sources. Appropriate power supplies are included in the unit, as are switches to control the operation of the recording racks.

Each of the three recorder racks contains a double recording unit consisting of cathode ray tubes and a continuous film camera. Appropriately timed gates from the monitor rack allow sweep generators to operate one after another and, at the same time, unblank the cathode ray tube so that the video pulses from the receiver in the monitor rack can be presented as intensity modulation on the tube. Necessary video amplifiers are included in this unit, as are circuits for mixing the video with timing signals and with the reference pulses generated by 10 kc matrix oscillator on the ground. There are also suitable controls for positioning and focusing the cathode ray tubes, as well as necessary power supplies.

The image on the face of the cathode ray tubes is focused on a slit on the front plate of the unit by means of two lenses, placed side by side. A film magazine is placed so that the image from both tubes is recorded on it as the film is drawn continuously past.

The total weight of the telemeter transmitter set, with batteries suitable for thirty minutes operation, is about 130 pounds. Two Willard type ER-8-28, 28 volt plastic cased storage batteries are used in conjunction with a vibrator type converter unit to provide the various plate voltage and bias supplies, plus four type ERH-25-2, 2-volt plastic cased storage batteries for the filament supplies. Total power requirements for the system are 15 amperes at 28 volts and 20 amperes at 8 volts.

The ground station operates on 110 volts, 60 cycles a.c. with a power con-

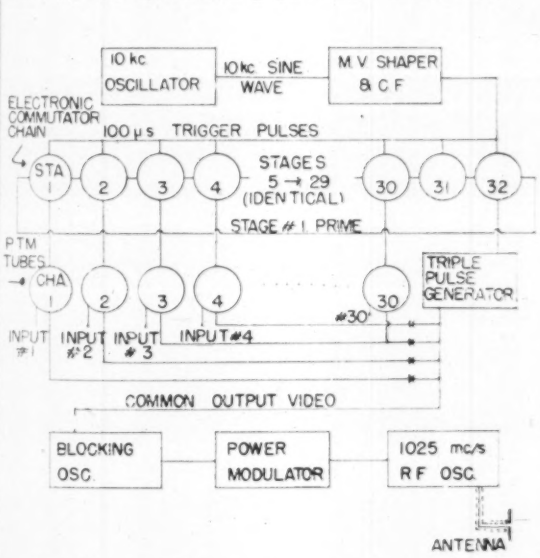


Fig. 4. Block Diagram, AN/DKT-2 Telemeter Transmitting Set

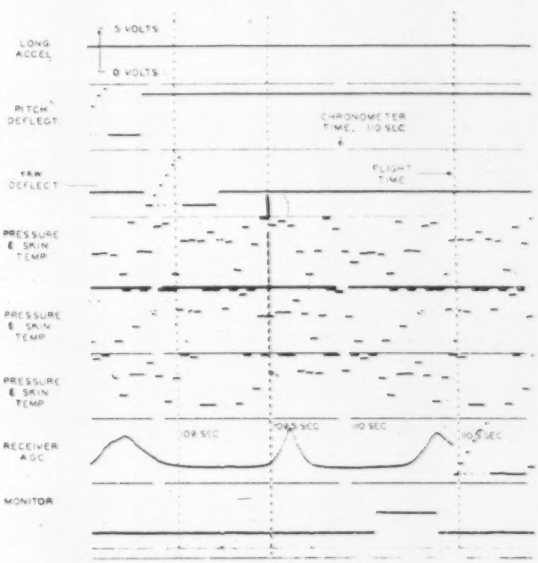


Fig. 5. Typical Record Station, Matrix Telemetering System

sumption of about 3000 watts. Voltage regulation of the primary power for these units is obtained from Sola Constant Voltage transformers. All plate supplies under 600 volts are electronically regulated against load variations. The high voltage supplies required for the cathode ray tubes are −2000 volts obtained from a conventional transformer-rectifier circuit, unregulated and +10,000 volts obtained from an r.f. power supply operated from an electronically regulated 300 volt power supply. Due to the complexity of the ground station circuits, and the number of tubes involved, two complete and separate ground stations are utilized for every flight.

In normal flights six 9½" film records of about 120 feet in length are produced, corresponding to about 450 seconds of flight. These films give a complete graph of voltage versus time for all 30 channels, and are reproduced in the form of black line paper prints.

Prior to the development of the Matrix system, the Naval Research Laboratory had developed and operated at White Sands a sequential telemetering system. This system, also utilizing pulse time modulation, sampled 23 channels of input data of from 0 to +5 volts at a rate of 180 samples per second, with a pulse output power of about 1.2 kw. This system utilized dry batteries for all plate supplies in the transmitter, and weighed 150 pounds installed. However, due to lack of a coded synchronizing pulse and due to the method of ground recording whereby each pulse received actuated a metering circuit, the sensitivity of the system to noise was appreciably greater than the Matrix system, giving frequent losses of recorded record at ranges in excess of 90 miles. Results with the Matrix system indicate that satisfactory noise free records far beyond this range are possible.

Industrial Radar For Hurricane Tracking*

By W. F. GERDES and R. C. JORGENSEN†

Introduction

AN explanation seems in order as to why an industrial corporation manufacturing chemicals has apparently invaded the province of the U. S. Weather Bureau in tracking tropical storms. The facts are that the program is not in competition with the Weather Bureau, but in cooperation with it; and it was undertaken in order to facilitate the chemical manufacture. A hurricane need come no closer than a hundred miles to cause thousands of dollars loss to the Dow Plants. The vulnerability of the site on the Texas Gulf Coast and the nature of some of its operations require that plant shut down be started about twelve hours before the occurence of hurricane winds. While the Weather Bureau's service usually provides from one to several days warning of the approach of a tropical storm, it would not be practical to keep the plant shut down at all times that a hurricane existed in the Gulf. An accurate method of tracking the storm is required that will permit shutting down only when it comes within a critical radius of the plant.

In seeking a method of pin-pointing hurricanes, several methods were considered. The standard system in the past has been reports from ships in the storm area plus direct observations by reconnaissance planes. Since most ship masters avoid storm areas, and airplane observations are very difficult and dangerous at night, this is not entirely satisfactory for keeping an accurate track of a storm.

The micro-barometric survey has been proposed for predicting the path of a hurricane. This is an extension of the centuries old technique of watching the barometer. It involves a study of the minute short time variations in atmospheric pressure, or the atmospheric pressure "waves" associated with the storm. Much work remains to be done on this system.

Micro-siesmic observations have been somewhat successful in some parts of the world. The earth vibrations caused by the storm waves and the ocean swell are recorded and analyzed. This system, however, holds little promise for the Gulf Coast because of the geological formation of this area.

The sferics method appeared favorable, and for several years Dow participated in a program based on this method. The system utilizes triangulation from simultaneous radio bearings of lightning static impulses from the storm. It requires several observation stations and very good communications and coordination among them. More work might have been done on this method, but for the promise shown by radar.

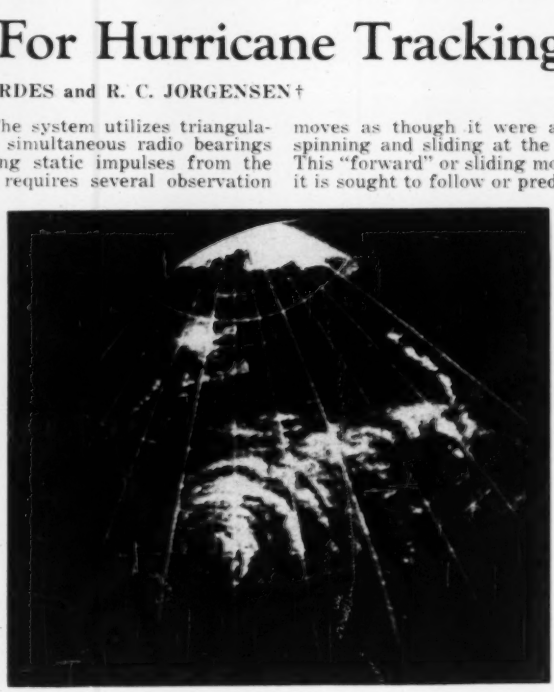


Fig. 1

The Hurricane Problem

Before proceeding further it appears proper to give a brief description of a hurricane: This will explain why it is so necessary to predict its approach hours or days in advance, and how it is possible to do so.

The hurricane is an area disturbance consisting of circular winds about a calm center or eye. Apparently most such storms originate in the tropics, but they travel far and may strike coastal areas anywhere in the tropical or temperate zones. Those in the northern hemisphere always rotate counterclockwise, while those in the southern hemisphere rotate clockwise as viewed from above. Hurricanes are usually dangerous over a diameter of 100 miles or more, with the worst winds near the center. The calm area at the center may be several miles in diameter, and barometric pressure may be as low as 27 inches. In addition to the very severe circular winds, which may exceed 100 miles per hour, the whole disturbance moves as though it were a giant top spinning and sliding at the same time. This "forward" or sliding motion, which it is sought to follow or predict, usually ranges from 4 to 15 miles per hour. However, the storm may stay in one spot for half a day or double back on its past track.

A single storm may have a life as long as two weeks, during which it traverses thousands of miles of ocean. Once the cycle is started, energy is poured into the storm continuously in the form of warm moist air. This causes heavy rains as it spirals in toward the center and the resulting pressure drop provides impetus for continued winds and more rain. The storm usually dissipates soon after hitting land areas, but these hurricanes cause much damage and loss of life on the Gulf and Atlantic coasts. They are invariably accompanied by extremely high tides and usually by torrential rains.

The inhabitants of inland areas may have difficulty in comprehending the destruction of a hurricane, considering that the hundred-and-twenty five mile an hour winds are only a fraction as great as those of a Great Plains twister. The explanation is in the large area covered and the high water. Tides of sixteen feet have been experienced along the Gulf Coast, and forty foot storm tides are not unusual in some areas. Add to this the fact that many coastal

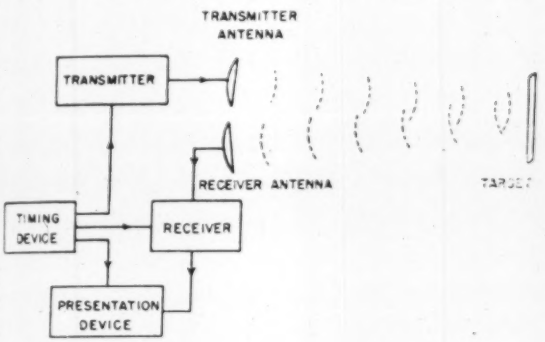
*Presented at the Fourth Annual Conference of the Instrument Society of America, Sept. 12-16, 1949, St. Louis, Mo.

†Dow Chemical Company, Freeport, Texas.

communities are from four to eight feet above sea level and it becomes apparent that cyclone cellars are of no value.

Several historic catastrophies have resulted from hurricanes, including those encountered by Columbus and the Spanish Armada. On October 7, 1737, a storm in the Bay of Bengal killed 300,000 persons, and in 1864 another in the same area killed 50,000. The Galveston storm of 1900 is a modern example of the fury of the Gulf Coast hurricane. This storm killed 2000 persons. A 1935 storm in Haiti killed 2000. In recent years the loss of life has been less, chiefly because of better warning and mass evacuation.

What property of a hurricane allows it to be detected by means of radar? During the war it was discovered that aircraft could hide in heavy rainstorms and avoid detection by some types of radar because the rain gave a radar indication of the same type as an airplane, but over a wide area. The indication was not changed by the presence of an aircraft in the rain area. Later it found that hurricanes presented a distinct picture on these radar sets because of the rain which almost invariably accompanies them. Fig. 1 shows a typical picture of the radar presentation of a hurricane on a plan position indicator. The picture is equivalent to a map or plan view of the area with the radar located at the convergence of the radial lines. These lines and the range circles form a polar coordinate reference system used to locate targets accurately with respect to the radar. The irregular white arcs represent radar reflections from the bands of heavy rains. Radar returns of this type have been found to result from hurricanes in all parts of the world, and have never been observed from any other cause. The picture shown was made from the 'scope of a 10 cm. Army radar during the 1945 hurricane which went up the Florida peninsula.



BLOCK DIAGRAM OF PULSED RADAR

Fig. 2

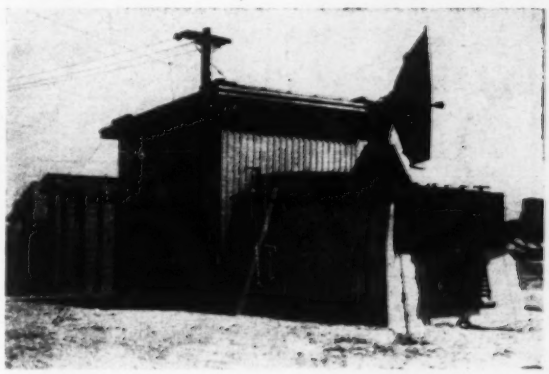


Fig. 3

How Radar Works

Radar is characterized by elaborate equipment and highly specialized techniques, but it is based upon very simple principles. Fundamentally it is an echo device, identical in principle to the methods of the steamer pilots who blew the whistle and counted the seconds until the echo returned from the shore. Knowing the velocity of sound, a simple calculation gave the distance to the echoing object. By using radio waves instead of sound, the range of the device can be greatly extended and the directional accuracy improved. Origin of the word radar is somewhat controversial, but it is said to be an abreviation of the words **RAdio Direction And Ranging.**

Fig. 2 shows the principal parts of a pulsed radar set in block form. The timing device serves as a program director for the entire set, controlling the transmitter, receiver, and the presentation device. Powerful pulses of radio energy are generated by the transmitter at the command of the timer. With the aid of reflectors similar to optical reflectors, these very short pulses of energy are radiated in a highly directional beam by the transmitting antenna. The receiver antenna and the receiver pick up the returned echo (if any) and send the notice of arrival to the presentation device. This device serves as a microstopwatch to measure the time required for the signal to echo from any target and gives a visual indication of this time. Usually the size and intensity of the echo and its azimuth bearing from the radar are also shown. In operation the timer causes the transmitter to send out a pulse of energy, at the same time starting the time-measuring process in the presentation device. The receiver is desensitized during the few millionths of a second that the transmitter functions so that the burst of energy will not paralyze it.

A single such pulse will give an indication of all the echo-producing objects in the path of the radio beam. However, since it may be desired to sweep the antenna rapidly through the complete 360 degres of rotation and scan the complete area covered by the radar, provisions must be made to send out rapidly recurring pulses. Thus the timer is designed to wait only the minimum time required for the reception of an echo from the maximum expected range before repeating the cycle. In the event the antenna is not rotated, recurring echo pulses are indicated in the same position on the indicator and are integrated by the persistence of the phosphor on the cathode ray tube to give a more distinct indication.

Practical radar sets may have arrangements considerably different from that shown and usually have numerous additional blocks which perform auxilliary functions. Most sets have only one antenna which functions alternately for the transmitter and the receiver through the use of an automatic switch. Power servo systems permit the operator to point the antenna in any desired direction by finger tip controls. Other devices may provide the automatic frequency control.

Radar for general use or search usually is equipped with a type of presentation known as the Plan Position Indicator. A more detailed description of this device will be of help on understanding the photographs of the radar screen. In this unit, time is measured by radial distance which a spot moves from the center of the cathode ray tube. Direction in which the spot moves is made to coincide with the direction in which the antenna is pointing. That is, the spot moves from the center upward when the antenna points north, and from the center to the right when the antenna points eastward. Direction of search of the antenna is under the control of the operator, but the direction of movement of the spot is always coordinated with it. The spot starts from the center at the time the radio wave is sent out, and moves from the center outward at constant speed. Reception of an echo is made to brighten the spot momentarily. Since travel time is proportional to the distance to the echo producing object, and time also is proportional to the radial distance the spot has moved on the indicator, this gives a bright spot for each echo-producing object in its map or plan aspect with reference to the radar set. Hence, the name Plan Position Indicator or PPI. Distance and angles may be scaled directly on this presentation.

The factors affecting radio propagation and the question of what causes a radio reflection or echo have been studied in great detail in connection with the wartime radar program. In general, any conductor of electricity or any insulator with properties greatly different from the atmosphere may cause a radio reflection. The reflection is usually diffuse, comparable to light reflected from a rough surface. To produce a strong echo, the object must be of a size comparable to or larger than a half wavelength of the radio wave. However, much smaller objects such as drops of water cause some reflection; and if there are enough of these objects in a given area, an echo will be received. Calculations show that the energy returned from a drop of water varies as the sixth power of the ratio of drop diameter to wavelength.[2]

Practically, this means that 3000 Mc or 10 cm radar sets will "see" rain, while 100 Mc or 500 Mc will not. Radar operating on 10,000 Mc or 3 cm will indicate the presence of light rain or fog. Water drops of a minimum diameter of about 1.2 millimeter are indicated by 10 cm radar. Another point which should be

emphasized is that an object need not be opaque to radio waves in order to produce an echo. Just as a pane of glass may transmit 90% of the light striking it and still give a reflection, so may an object produce a radio echo and still transmit a large percentage of the signal. At times as many as three rainstorms in a row radially from a radar have been seen in the radar 'scope.

Radio energy of wavelengths commonly used in radar work travels essentially in straight lines, just as light does, and diminishes as the square of the distance from the source. Under normal atmospheric conditions there is a slight bending in the vertical plane which extends the radar horizon slightly beyond the optical horizon. To be "seen" by a radar set with its antenna at 25 feet elevations, an object at a range of 100 miles must have an elevation of about 4,000 feet, while at 300 miles an object must be about 40,000 feet high.* Thus, it is seen that there is a definite limit to the range that may be attained, even though a very large amount of power is used. Meterologists are in general agreement that the central core of a hurricane may rise to 50,000 feet, but the maximum height at which water drops are present is probably somewhat less. Because of these considerations, it appears that no radar of present design located on the ground will be able to detect a hurricane at ranges much in excess of 300 miles. Occasionally radar targets are detected at ranges far beyond the optical horizon. This is caused by anomalons atmospheric conditions which create a duct or layer through which radio waves are led around the earth's curvature. Unfortunately this phenomena cannot be relied upon to extend radar coverage.

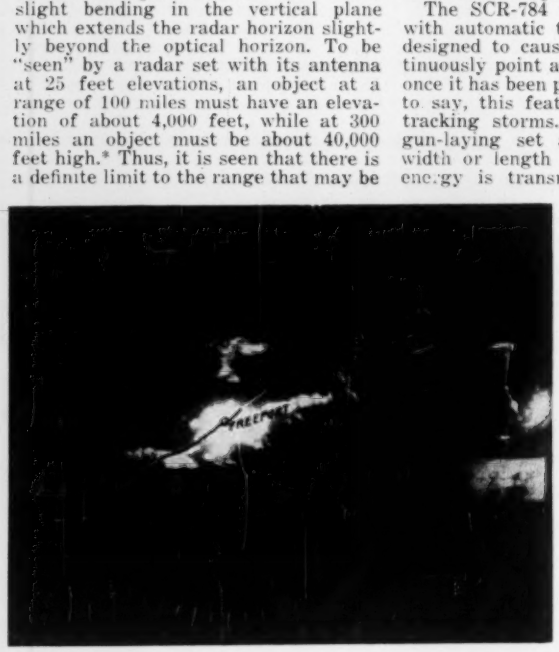


Fig. 4

Installation Details

When it was decided to install a radar set for the purpose of tracking storms, the question of the most suitable type arose. The Weather Bureau recommended the SCR-584 or 784 since these sets are designed for about 3000 Mc (10 cm) and have adequate power. A trailer-mounted SCR-784 was purchased and certain necessary modifications were made with the assistance of Weather Bureau personnel. The installation was made under terms of an agreement whereby all data obtained with the radar would be sent directly to the Weather Bureau and would be released to the public only through that agency. A federal communications commission license was obtained for the radar station.

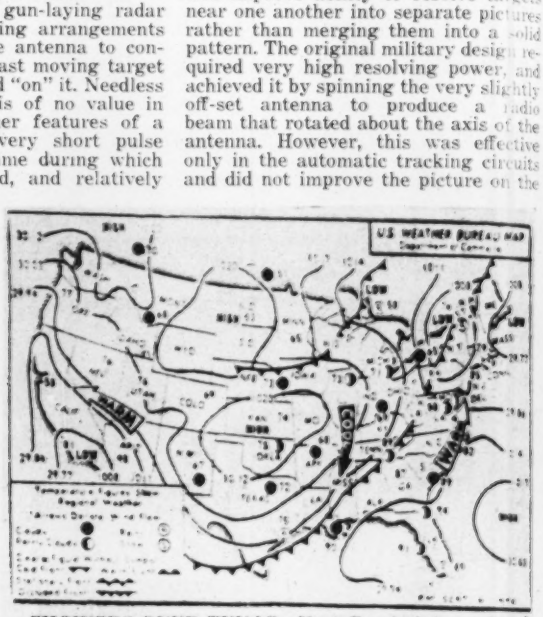
The set was located about two miles from the open Gulf on land about 18 feet above sea level, with a clear view seaward. The trailer was supported on a concrete foundation and a stout, well guyed building was constructed around it. An emergency gasoline power unit was housed separately nearby. Fig. 3 shows the complete installation.

The SCR-784 is a gun-laying radar with automatic tracking arrangements designed to cause the antenna to continuously point at a fast moving target once it has been placed "on" it. Needless to say, this feature is of no value in tracking storms. Other features of a gun-laying set are very short pulse width or length of time during which energy is transmitted, and relatively short design range. This does not imply a lack of power, but rather a short listening period between transmitted pulses. The peak power of the set during the .8 microsecond transmitted pulse is 250 kilowatts, or five times that of the most powerful commercial broadcast station.

Modification of the set for the weather work began with a slowing of the pulse repetition frequency to give more listening time between transmitted pulses. Additional multivibrator stages were added to the timing circuits to give a frequency of 188 pulses per second, which permits reception of echoes from objects 300 miles distant. Then the presentation unit was modified to cause the cathode ray spot to sweep more slowly, corresponding to the time required to receive echoes from the longer range. Multiple ranges of 100, 200, and 300 miles were provided, with a selector switch to choose among them. It must be recognized that range as used here refers to the distance equivalent of time of sweep of the indicator oscilloscope. Any arbitrary range may be placed on the 'scope up to the limiting time interval between transmitted pulses; however, there is no assurance that echoes will be received from these wholly arbitrary ranges. Range marker circuits were changed to give reference marks on the PPI 'scope corresponding to ranges of 20 mile increments. These assist in determining the exact range to a target, since the indicator circuits may have faults which result in non-linearity of the picture.

This completed the necessary modifications, but several others were made in the interest of improved efficiency. A larger parabolic antenna reflector was installed in order to focus the radio waves into a sharper beam and thus give a higher concentration of energy and improve ability to resolve targets near one another into separate pictures rather than merging them into a solid pattern. The original military design required very high resolving power, and achieved it by spinning the very slightly off-set antenna to produce a radio beam that rotated about the axis of the antenna. However, this was effective only in the automatic tracking circuits and did not improve the picture on the PPI oscilloscope. The larger reflector improved the PPI resolution as well as giving the effect of increased transmitter power and receiver sensitivity.

The slowing of the pulse repetition frequency previously mentioned resulted in a reduction in the average energy transmitted by the station, since each pulse contains a definite energy and the number per second was reduced. In order to increase this average energy output, the pulse width or time during which the transmitter is energized was increased from the original .8 microsecond to 1.6 microsecond. In general, average power is unimportant so long as peak power is maintained, but a pulse of longer duration improves the signal from a diffuse object or one with depth, such as a rainstorm. This greater pulse width gives poorer resolution in range, but it is still more than adequate. From consideration of the speed of radio waves as 186,000 miles per second, or one two-way mile in approximately 11 microseconds, a pulse of 1.6 microseconds duration gives a possible resolution in range of about one-seventh mile. However, this cannot be realized on a small PPI presentation. An expanded sweep of a portion of the listening time interval would show details of



SHOWERS OVER TEXAS—East Coast states enjoyed fair and warm weather. Showers and thunderstorms were reported from the St. Lawrence valley southwestward to extreme Southern Texas. Most of the Western states had a fair, mild day Thursday.

Fig. 5

* $R = 1.43\ (\sqrt{H_1} + \sqrt{H_2})$ Where R is range in miles and H_1 and H_2 are heights of radar and target in feet.

this order. While this would be interesting, it does not come within the scope of the program for practical hurricane tracking. The angular resolution of the modified equipment is of the order of two degrees, which means that at a range of 100 miles isolated objects less than four miles apart will have their echoes merged. This difference between angular and range resolution causes point targets to produce elongated pictures with the long axis tangent to range circles.

Other modifications made included installation of a new pre-amplifier and a larger PPI tube. The pre-amplifier for the receiver was of newer and more efficient design, giving better receiver performance. A larger PPI tube added nothing to range or sensitivity of the equipment, but permits a more detailed study of echoes. Camera equipment was arranged to permit rapid photographing of the screen with convenient means for identifying each picture as to date and hour. An automatic camera was also arranged to take a picture every minute. When projected as a movie film, the record of this camera should be very interesting. As modified, the equipment is considered entirely satisfactory for weather work. The most serious limitation is that imposed by the horizon, or the curvature of the earth.

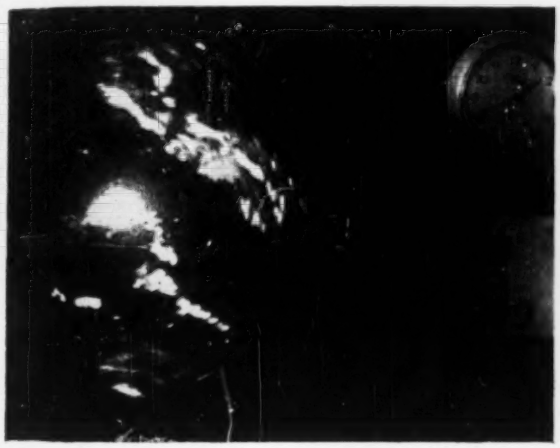


Fig. 6

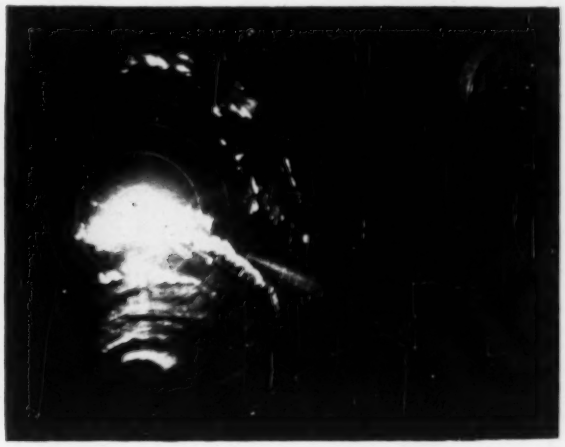


Fig. 7

Results

After the equipment was installed and modified, many observations were made to test the range and accuracy. Thunderstorms and isolated rains were observed and telephone calls were placed to verify the actual weather at the points where rain was indicated. Agreement was surprisingly good. This process was sometimes rather amusing when a distant airport or weather station was called and the attendant was asked a series of questions apparently based on mindreading or intuition. Questions such as, "Has it been raining there for about fifteen minutes?" or "Did the rain storm approach from the northeast?" usually evoked surprise and amazement—at least when the answers were affirmative. Some cases of disagreement were apparently caused by rain in the upper atmosphere which evaporated before striking the ground. Results were consistent enough to indicate that rain will always be indicated. Many storms have been observed at ranges greater than 200 miles, at least one at 240 miles being verified. Echoes from 280 miles have been observed. Several times the radar screen has presented a picture of a line squall that agreed very closely with a front indicated on the official weather maps. Figures 4 and 5 indicate one case of this type. Geographical features were dubbed in to better orient the 'scope photograph. This picture also illustrates a case of the radio waves penetrating 80 miles of solid rain and still retaining power to produce an echo from rain 100 miles distant.

A program was set up for daily observations during the hurricane season —from the middle of June to the first of November. Daily observations are considered sufficient at times when no hurricanes are known or suspected to be within range of the equipment. When general weather observations indicate the likelihood of storms, the Weather Bureau requests that additional observations be made. The results of all such observations are sent to the Weather Bureau.

In the event that a tropical storm is known to be approaching, the equipment is manned continuously. A weather consultant is on hand to interpret the results and direct the experimental program. Experience during the war indicates that considerable information about a hurricane may be revealed by one observation on the radar screen. The center or eye of the storm is usually well defined as a clear area completely or partially surrounded by heavy rain. Even before the main part of the storm comes within range, the squall line associated with it may provide some information. These squalls may be from 40 to 100 miles from the center and they are thought to run at right angles to the line of progress of the storm. It is also generally acknowledged that rains are heaviest in the right front quadrant of the moving storm—this is based on storms in the northern hemisphere, which always have counterclockwise rotation as viewed from above. When observing a storm moving radially, that is, approaching the radar, the movement should be apparent from observations taken 15 minutes apart. This contemplates a speed of four miles per hour and a range resolution of the radar of one mile.

As an experimental program, efforts will be made to obtain a vertical profile of the hurricane core by taking successive photographs as the angle of antenna elevation is increased. If this is successful at all, it will probably be at rather short ranges, since the angular resolution is hardly adequate for this.

Fortunately, the hurricane data obtained thus far with this equipment has been of a negative nature. That is, the first hurricane season and a portion of the second have elapsed with no hurricanes having presented themselves for observation. This does not dampen enthusiasm for the program in any way. The range and reliability of the equipment having been proved on rainstorms, Company management can rely on the absence of hurricane patterns with as much confidence as if a storm were pictured on the screen—and with considerably more complacency. It must be acknowledged that the hurricane which struck New Orleans on September 3, 1948, passed within 300 miles of the radar. The Weather Bureau's track shows it passing about 270 miles to the east of Freeport. No indication of a hurricane or even of rain was obtained during its course. However, this particular disturbance barely qualified as a hurricane, the highest wind velocity being 70 miles an hour. Undoubtedly it did not reach the altitude required for radar observation at this extreme range.

Conclusions

No attempt will be made to draw conclusions regarding the radar method of tracking hurricanes. The method was verified by numerous cases during the war, the most widely publicized one being the September 14 to 15, 1945, hurricane which was tracked up the Florida Peninsula by a 10 centimeter radar at Orlando.

The equipment as installed and modified at Freeport, Texas, has been found to be accurate and reliable. Although no hurricane has been observed, results on rainstorms indicate a conservative range of 200 miles. From the vewpoint of Company management, the program has been practical and valuable in maintaining uninterrupted plant operation during threatened hurricanes. As a consequence of the demonstrated practicability of radar equipment and the previous success of the Army in tracking hurricanes, it seems very desirable to have overlapping coverage of the entire Gulf

and lower Atlantic Coasts. With a chain of these modified weather radar stations and the increasing use of general navigational radar by ocean vessels, tremendous improvements in detecting and tracking hurricanes should be realized. Besides permitting intelligent evacuation of threatened areas, this will provide a powerful tool for expanding the knowledge of these terrible storms.

Author's Note

Since presentation of the above article at the September Instrument Conference in St. Louis, some new and interesting results have been obtained with the equipment. During the Gulf hurricane of October 2-4, 1949, the set was operated during the 24 hour interval before the storm hit the coast and still and moving pictures of the screen were made.

When first spotted by the Weather Bureau, this storm was nearly 600 miles south of the radar equipment, but it moved rapidly northward and shortly after noon of October 3 it was reported within 200 miles of the station. At that time the scope showed two long squall lines of definite curvature, but there were no positive indications of a hurricane. There was a single bright echo near the reported center of the storm. By 1:30 this spot had added faint concentric arcs and was definitely identified as the storm center. Figure 6 shows a photograph made at 1:40 p.m, October 3. As the storm continued to approach the station, its forward progress was estimated with good accuracy. Figure 7 shows a photograph made shortly before the equipment was shut down for fear of wind damage.

The storm passed inland about 15 miles west of the station at midnight. Maximum winds at the radar were 91 miles an hour, and tide was eleven feet above mean low tide. This was not a severe hurricane, and damage was largely confined to growing crops and utility lines.

Detection of this rather mild hurricane at a range of 180 miles confirms previous estimates of the reliable range of the equipment and demonstrates its value in providing warning of approaching storms.

References

[1] I. R. TANNEHILL, HURRICANES, *Princeton University Press.*

[2] FRIEND, TROPOSPHERIC SOUNDING BY RADAR, *Proceedings of IRE*, Feb., 1949.

[3] R. H. MAYNARD, RADAR AND WEATHER, *Journal of Meteorology*, Vol. 2, No. 4, Dec., 1945.

[4] H. WEXLER, STRUCTURE OF HURRICANES AS DETERMINED BY RADAR, *Annals of New York Academy of Sciences*, Vol. XLVIII, Sept. 15, 1947.

[5] JOSEPH WEIL and WAYNE MASON, THE LOCATION OF TROPICAL STORMS BY MEANS ASSOCIATED STATIC, Bulletin No. 3, Engineering Experiment Station, University of Florida.

[6] J. B. MACELWANE, THE PROBLEM OF MICROSEISMS AND OCEAN STORMS, *Bulletin of the Seismological Society of America*, April, 1946.

Section Data continued from page 65

tenance Clinic moderated by Charles B. Cochran, Peter Loftus Corp.
February 27, "Detection of Toxic and Explosive Gases," N. W. Hartz, Mine Safety Appliances Co.

Pittsburgh Inspection & Gaging Committee. Meeting at 8:00 P. M.
January 10, "Inspection in the Machine Shops Handling Large Heavy Work of High Degree of Accuracy," G. W. Linkhauer, United Engineering & Foundry Co.
February 14, "The Laboratory and its Relation to Inspection," C. E. McFarlane, Westinghouse Air Brake Co.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa.
Fourth Tuesday, Meeting at 8:00 P.M.
January 24, Open forum on instrumentation problems.
February 27, "Control Valves," T. L. Smith, Belfield Valve Div., Minneapolis-Honeywell Regulator Co.

RICHLAND
M. T. Slind, M-6, Rm. 107, Richland, Washington
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y.
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester.

SARNIA
Fred T. Yorke, P. O. Box 213, Point Edward, Ontario, Canada
Second Friday, Moose Hall.

SOUTH BEND
Sam M. Rouse, 436 Moccasin Ave., Buchanan, Mich.
First Thursday, Meeting at 8:00 P.M., Engineers Club, South Bend.

SOUTH MICHIGAN
Larry DeHann, 1117 Cobb Ave., Kalamazoo, Mich.
Second Wednesday, Dinner at 6:30 P.M. Meeting at 8:00 P.M.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Farfurrias, Texas
First Thursday, Meeting at 7:30 P.M., Garner Aircraft Instrument School.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo.
First Wednesday, Meeting at 8:00 P.M., Engineers' Club of St. Louis.
February 8, "pH Control," Dr. A. O. Beckman, National Technical Labs.
March 8, "Chemical Process Control," Hart U. Fischer, Monsanto Chemical Co.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn.
No definite night, Dinner at 6:45 P. M., Meeting at 8:00 P.M.

TULSA
C. R. Horton, 8211 E. 7th, Tulsa, Oklahoma
First Monday, Meeting at 6:45 P.M., Tulsa Univ.

TWIN CITIES
Alden Hine, c/o Giesika & Pinkney, 552 Plymouth Bldg., 6th & Hennepin Ave., Minneapolis 2, Minn.
Fourth Tuesday, Dinner at 6:30 P.M.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md.
Third Monday, Meeting at 8:00 P.M., Pepco Auditorium.

WAYNE COUNTY
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan
Third Monday, Dinner at 6:30 P.M., Meeting at 8:30 P.M., Poremba Hotel, Ecorse, Mich.

WILMINGTON
Dean Valentine, 34 N. Hill Drive, West Chester, Pa.

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA, 921 Ridge Ave., Pittsburgh 12, Pa.

INSTRUMENT SALES ENGINEER. Opening for man with mechanical and electronic engineering background with sales experience and aptitude. Work with research type instruments with some industrial applications. Position involves technical correspondence, application work, some traveling. Location: Cleveland. Box 267.

• • •

PHYSICIST. For design and development of electronic and mechanical instrumentation equipment used in the pursuit of flight research work. Several years of theoretical and practical experience necessary. Salary commensurate with qualifications. Permanent position. Give details in first letter. Location: Buffalo. Box 268.

• • •

DESIGNER or draftsman experienced in time clock mechanisms. Old, medium-size company, near New York City. Give complete resume of background in first letter. Box 269.

• • •

PHYSICISTS, PHYSICAL CHEMISTS, RESEARCH METALLURGISTS of Ph. D. level or equivalent, with training and experience in physics of solids, theoretical physics, nuclear physics, chemical kinetics, plasticity of metals, diffusion of solids are needed in the Research Department of Westinghouse Atomic Power Division. The work is concerned with the development of nuclear power sources, and includes studies of the effect of radiation on materials, creep and diffusion in metals, neutron physics of reactors, and experimental nuclear physics. These positions offer unique opportunities for participation in a research and development project with stimulating immediate and long-term objectives. Write giving particulars of experience and professional references. Location: Pittsburgh, Pa. Box 270.

• • •

ELECTRONIC ENGINEERS OR PHYSICISTS with from 3 to 10 years' experience in the following fields: (a) UHF and VHF circuit and antennae design, (b) design of servomechanisms and control circuits, (c) design of carrier-type strain-gage recording systems. The position will require personnel who can supervise engineers and/or technicians, design equipment and follow construction and necessary trouble-shooting after installation. This work is required for the flight testing of piloted and pilotless aircraft. Chance Vought Aircraft, Dallas, Texas. Box 271.

• • •

DESIGN ENGINEER OR SENIOR DRAFTSMAN by Instrument Manufacturer for design of cabinets and cases for electronic equipment for Government specific end use such as shipboard installation, man-borne equipment and portable cabinets for field use. These units must be designed with specific thought to such factors as weight, size, weather tests, splashproof or immersion requirements, plus finishes in accordance with Government specs. Some knowledge of gears, differentials and other mechanical components. Knowledge of shop equipment so as to design parts with minimum amount of special tooling. Adequate housing available. Location: Hampton, Va. Box 272.

• • •

INSTRUMENT MECHANICS. Two. Thoroughly qualified installing, calibrating, and servicing all types of measurement and control instruments used for chemical or refinery process control. Must be particularly well versed in pneumatic control and transmission instruments and devices. Starting rate $2.01 per hour with benefits and opportunities of a large company. Advancement to $2.10 per hour after six months. Include in first letter complete details of experience, training, education and availability. Location near Elizabeth, N. J. Box 273.

• • •

INSTRUMENT PERSONNEL. Draftsmen, Designers, Project Engineers. Experienced in aircraft or industrial pressure instruments, gyroscopes, flight-test instrumentation and controlling switches. Give full details of background in first letter. Location: California. Box 274.

• • •

SUPERVISOR OF ELECTRONICS AND INSTRUMENTATION responsible for selection, design and development of special purpose instruments for the measurement and recording of flight test data and for the installation of test equipment. Preliminary analysis of test results and preparation of formal reports for dynamic testing of experimental and production aircraft. Supervisory responsibility of fifty engineers and technicians. Preparation of time schedules for tests to meet dates and cost estimates to meet budgetary requirements. Must be engineering graduate with broad knowledge of mathematics, physics and with a specialized knowledge of aircraft instrumentation and electronics. Location: Texas. Box 275.

• • •

DEVELOPMENT AND APPLICATION ENGINEER. Experienced in designing, building, and field application of specialized electrical and mechanical and test equipment. Opportunity to introduce, develop and apply new test equipment in utilities, industrials and railroads. Well established, medium-size company. Location: East. Box 276.

JOURNAL of the Southern California Meter Association

President: R. Frank Fields — Auditor: John T. H. Morris
Vice-President: James E. Adams — Past-President: J. C. Groenewegen
Secretary-Treasurer: George H. Forster, 2916 Eucalyptus Ave., Long Beach 6, Calif.

History *of* Bellows-actuated Flow Meters*

By CLAUDE B. NOLTE, Vice President, Barton Instrument Corporation, Los Angeles, Calif.

IN 1886, a distinguished American engineer, Clemens Herschel, perfected a device for determining the rate of flow of water through conduits by measuring the difference in pressure at two positions in the conduit, where the flow stream has two different velocities. His primary device, the forerunner of the present-day orifice plate, was called a Venturi tube in honor of the Italian physicist, G. B. Venturi, who in 1797 formulated the principles on which the measurement of flow through differential producers is based. The development of Venturi tubes, orifices, nozzles, etc., created the need for practical industrial instruments for measuring pressure differences and led to the development of a whole new field of science and industry: precise differential pressure measurement on a commercial scale.

Glass-tube manometers for measuring differential pressures were known as far back as the middle ages and may have been used by Roman engineers for measuring static pressures in the great waterworks system in Rome. These pioneer engineers were aware of methods of regulating water flows. The service connections on the city water mains were fitted with stopcocks much the same as we use today. Beyond each stopcock a straight, smooth restriction tube of definite diameter and length was placed in the piping to limit the amount of water each householder might withdraw. Presumably, the customer paid so much a month for a certain size tube, a greater amount for a larger one. Thus, although flow metering as we know it today began sixty years ago, the rudiments, at least, were recognized nearly 2000 years ago.

Today, the successful use of Venturi tubes, and of other primary devices, requires a sensitive instrument for measuring accurately small changes in pressure differences, even when static pressures are high. The familiar mercury-filled U-tube manometer has undergone vast improvements (Fig. 1). Today, the level of the mercury is no longer observed through glass walls: Instead, a metallic float follows the level of the mercury in the larger chamber. The use of chambers with two different diameters reduces the travel of the float so that its position

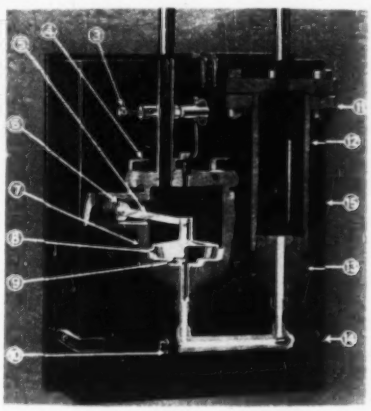


Fig. 1

may be readily transmitted outside the pressure casing through a system of levers and shafts. A seal is made around the main transmission shaft by a precision lapped bearing of stainless steel; or magnetic couplings do away with the need of stuffing-boxes, etc., for sealing shafts. In its present form, the float type manometer is widely used in industry. For many applications, it is doubtful indeed if any other mechanism will ever take its place. Still, it does have limitations.

The float type manometer doesn't lend itself readily to use aboard aircraft where the instrument may be subjected to forces of a lateral type which tend to drive the float against the case or its guide rods. The float type manometer may be made portable but it must be leveled precisely to obtain accurate results. Moreover, the weight of the mercury alone makes a lightweight unit difficult to produce. If an excessive differential pressure is applied, the mercury may be blown out of the instrument and lost. Even though check valves and mercury catch-pots have been devised to prevent or reduce these losses, mercury consumption is still high. This is not only caused by over-ranging, but by the activities of the mercury thief as well. A float type recorder contains enough mercury to make an evening's work for the thief quite profitable.

These problems are only annoyances, however. The primary reason that other means of differential pressure measurement have been sought stem from something more basic. Mercury forms explosive compounds with common chemicals such as ammonia. Apparently, the compounds are stable at high pressures and break down only when disturbed after the pressure has been released. The float type meter may be safe enough when in service but may become a "booby trap" for the unwary repair man.

The photographic industry demands chemicals that are produced without contact with mercury. The liquid metal, even if present in only minute quantities, will fog photographic emulsions just as readily as light, x-rays, or nuclear reactions. Consequently, flow meters containing mercury can't be used in plants producing solvents used to make acetate film, for example.

Some of the organic sulphur compounds act as emulsifying agents for mercury and petroleum. When the specific gravity of the mercury column in a float type meter is altered by emulsification, the calibration is changed

*Presented before the Southern California Meter Association.

FEBRUARY MEETING
"HI-JINKS"

Saturday the 18th, Rio Hondo Country Club, Downey, Calif. Dinner at 6; festivities until 11 p.m. Non-members cordially invited.

THERON S. CODY
Publicity Chairman

Correction: Paul RENFREW (not Renfrew) is the name of the January speaker. Sorry we misspelled it in last month's meeting notice. —T.S.C.

and lower Atlantic Coasts. With a chain of these modified weather radar stations and the increasing use of general navigational radar by ocean vessels, tremendous improvements in detecting and tracking hurricanes should be realized. Besides permitting intelligent evacuation of threatened areas, this will provide a powerful tool for expanding the knowledge of these terrible storms.

Author's Note

Since presentation of the above article at the September Instrument Conference in St. Louis, some new and interesting results have been obtained with the equipment. During the Gulf hurricane of October 2-4, 1949, the set was operated during the 24 hour interval before the storm hit the coast and still and moving pictures of the screen were made.

When first spotted by the Weather Bureau, this storm was nearly 600 miles south of the radar equipment, but it moved rapidly northward and shortly after noon of October 3 it was reported within 200 miles of the station. At that time the scope showed two long squall lines of definite curvature, but there were no positive indications of a hurricane. There was a single bright echo near the reported center of the storm. By 1:30 this spot had added faint concentric arcs and was definitely identified as the storm center. Figure 6 shows a photograph made at 1:40 p.m, October 3. As the storm continued to approach the station, its forward progress was estimated with good accuracy. Figure 7 shows a photograph made shortly before the equipment was shut down for fear of wind damage.

The storm passed inland about 15 miles west of the station at midnight. Maximum winds at the radar were 91 miles an hour, and tide was eleven feet above mean low tide. This was not a severe hurricane, and damage was largely confined to growing crops and utility lines.

Detection of this rather mild h rricane at a range of 180 miles con rms previous estimates of the reliable r nge of the equipment and demonstrat its value in providing warning of approaching storms.

References

[1] I. R. TANNEHILL, HURRICANES, P nceton University Press.

[2] FRIEND, TROPOSPHERIC SOUNDIN BY RADAR, *Proceedings of IRE*, Feb., 1949.

[3] R. H. MAYNARD, RADAR AND WE THER, *Journal of Meteorology*, Vol. 2, No. 4, Dec., 1945.

[4] H. WEXLER, STRUCTURE OF HURRICANES AS DETERMINED BY RADAR, *Annals of New York Academy of Sciences*, Vol. XLVIII Sept. 15, 1947.

[5] JOSEPH WEIL and WAYNE MASON, THE LOCATION OF TROPICAL STORMS BY MEANS ASSOCIATED STATIC, Bulletin No. 3, Engineering Experiment Station, University of Florida.

[6] J. B. MACELWANE, THE PROBLEM OF MICROSEISMS AND OCEAN STORMS, *Bulletin of the Seismological Society of America*, April, 1946.

Section Data continued from page 65

tenance Clinic moderated by Charles B. Cochran, Peter Loftus Corp.
February 27, "Detection of Toxic and Explosive Gases," N. W. Hartz, Mine Safety Appliances Co.

Pittsburgh Inspection & Gaging Committee.
Meeting at 8:00 P. M.
January 10, "Inspection in the Machine Shops Handling Large Heavy Work of High Degree of Accuracy," G. W. Linkhauer, United Engineering & Foundry Co.
February 14, "The Laboratory and its Relation to Inspection," C. E. McFarlane, Westinghouse Air Brake Co.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa.
Fourth Tuesday, Meeting at 8:00 P.M.
January 24, Open forum on instrumentation problems.
February 27, "Control Valves," T. L. Smith, Belfield Valve Div., Minneapolis-Honeywell Regulator Co.

RICHLAND
M. T. Slind, M-6, Rm. 107, Richland, Washington
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y.
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester.

SARNIA
Fred T. Yorke, P. O. Box 213, Point Edward, Ontario, Canada
Second Friday, Moose Hall.

SOUTH BEND
Sam M. Rouse, 436 Moccasin Ave., Buchanan, Mich.
First Thursday, Meeting at 8:00 P.M., Engineers Club, South Bend.

SOUTH MICHIGAN
Larry DeHann, 1117 Cobb Ave., Kalamazoo, Mich.
Second Wednesday, Dinner at 6:30 P.M. Meeting at 8:00 P.M.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Farfurrias, Texas
First Thursday, Meeting at 7:30 P.M., Garner Aircraft Instrument School.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo.
First Wednesday, Meeting at 8:00 P.M., Engineers' Club of St. Louis.
February 8, "pH Control," Dr. A. O. Beckman, National Technical Labs.
March 8, "Chemical Process Control," Hart U. Fischer, Monsanto Chemical Co.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn.
No definite night, Dinner at 6:45 P. M., Meeting at 8:00 P.M.

TULSA
C. R. Horton, 8211 E. 7th, Tulsa, Oklahoma
First Monday, Meeting at 6:45 P.M., Tulsa Univ.

TWIN CITIES
Alden Hine, c/o Giesika & Pinkney, 552 Plymouth Bldg., 6th & Hennepin Ave., Minneapolis 2, Minn.
Fourth Tuesday, Dinner at 6:30 P.M.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab., White Oak, Md.
Third Monday, Meeting at 8:00 P.M., Pepco Auditorium.

WAYNE COUNTY
Robert Karr, 2455 Biddle Ave., Wyandotte, Michigan
Third Monday, Dinner at 6:30 P.M., Meeting at 8:30 P.M., Poremba Hotel, Ecorse, Mich.

WILMINGTON
Dean Valentine, 34 N. Hill Drive, West Chester, Pa.

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA, 921 Ridge Ave., Pittsburgh 12, Pa.

INSTRUMENT SALES ENGINEER. Opening for man with mechanical and electronic engineering background with sales experience and aptitude. Work with research type instruments with some industrial applications. Position involves technical correspondence, application work, some traveling. Location: Cleveland. Box 267.

• • •

PHYSICIST. For design and development of electronic and mechanical instrumentation equipment used in the pursuit of flight research work. Several years of theoretical and practical experience necessary. Salary commensurate with qualifications. Permanent position. Give details in first letter. Location: Buffalo. Box 268.

• • •

DESIGNER or draftsman experienced in time clock mechanisms. Old, medium-size company, near New York City. Give complete resume of background in first letter. Box 269.

• • •

PHYSICISTS. PHYSICAL CHEMISTS, RESEARCH METALLURGISTS of Ph. D. level or equivalent, with training and experience in physics of solids, theoretical physics, nuclear physics, chemical kinetics, plasticity of metals, diffusion of solids are needed in the Research Department of Westinghouse Atomic Power Division. The work is concerned with the development of nuclear power sources, and includes studies of the effect of radiation on materials, creep and diffusion in metals, neutron physics of reactors, and experimental nuclear physics. These positions offer unique opportunities for participation in a research and development project with stimulating immediate and long-term objectives. Write giving particulars of experience and professional references. Location: Pittsburgh, Pa. Box 270.

• • •

ELECTRONIC ENGINEERS OR PHYSICISTS with from 3 to 10 years' experience in the following fields: (a) UHF and VHF circuit and antennae design, (b) design of servomechanisms and control circuits, (c) design of carrier-type strain-gage recording systems. The position will require personnel who can supervise engineers and/or technicians, design equipment and follow construction and necessary trouble-shooting after installation. This work is required for the flight testing of piloted and pilotless aircraft. Chance Vought Aircraft, Dallas, Texas. Box 271.

• • •

DESIGN ENGINEER OR SENIOR DRAFTSMAN by Instrument Manufacturer for design of cabinets and cases for electronic equipment for Government specific end use such as shipboard installation, man-borne equipment and portable cabinets for field use. These units must be designed with specific thought to such factors as weight, size, weather tests, splashproof or immersion requirements, plus finishes in accordance with Government specs. Some knowledge of gears, differentials and other mechanical components. Knowledge of shop equipment so as to design parts with minimum amount of special tooling. Adequate housing available. Location: Hampton, Va. Box 272.

• • •

INSTRUMENT MECHANICS. Two. Thoroughly qualified installing, calibrating, and servicing all types of measurement and control instruments used for chemical or refinery process control. Must be particularly well versed in pneumatic control and transmission instruments and devices. Starting rate $2.01 per hour with benefits and opportunities of a large company. Advancement to $2.10 per hour after six months. Include in first letter complete details of experience, training, education and availability. Location near Elizabeth, N. J. Box 273.

• • •

INSTRUMENT PERSONNEL. Draftsmen, Designers, Project Engineers. Experienced in aircraft or industrial pressure instruments, gyroscopes, flight-test instrumentation and controlling switches. Give full details of background in first letter. Location: California. Box 274.

• • •

SUPERVISOR OF ELECTRONICS AND INSTRUMENTATION responsible for selection, design and development of special purpose instruments for the measurement and recording of flight test data and for the installation of test equipment. Preliminary analysis of test results and preparation of formal reports for dynamic testing of experimental and production aircraft. Supervisory responsibility of fifty engineers and technicians. Preparation of time schedules for tests to meet dates and cost estimates to meet budgetary requirements. Must be engineering graduate with broad knowledge of mathematics, physics and with a specialized knowledge of aircraft instrumentation and electronics. Location: Texas. Box 275.

• • •

DEVELOPMENT AND APPLICATION ENGINEER. Experienced in designing, building, and field application of specialized electrical and mechanical and test equipment. Opportunity to introduce, develop and apply new test equipment in utilities, industrials and railroads. Well established, medium-size company. Location: East. Box 276.

JOURNAL of the Southern California Meter Association

President: R. Frank Fields — Auditor: John T. H. Morris
Vice-President: James E. Adams — Past-President: J. C. Groenewegen
Secretary-Treasurer: George H. Forster, 2916 Eucalyptus Ave., Long Beach 6, Calif.

History *of* Bellows-actuated Flow Meters*

By CLAUDE B. NOLTE, Vice President, Barton Instrument Corporation, Los Angeles, Calif.

IN 1886, a distinguished American engineer, Clemens Herschel, perfected a device for determining the rate of flow of water through conduits by measuring the difference in pressure at two positions in the conduit, where the flow stream has two different velocities. His primary device, the forerunner of the present-day orifice plate, was called a Venturi tube in honor of the Italian physicist, G. B. Venturi, who in 1797 formulated the principles on which the measurement of flow through differential producers is based. The development of Venturi tubes, orifices, nozzles, etc., created the need for practical industrial instruments for measuring pressure differences and led to the development of a whole new field of science and industry: precise differential pressure measurement on a commercial scale.

Glass-tube manometers for measuring differential pressures were known as far back as the middle ages and may have been used by Roman engineers for measuring static pressures in the great waterworks system in Rome. These pioneer engineers were aware of methods of regulating water flows. The service connections on the city water mains were fitted with stopcocks much the same as we use today. Beyond each stopcock a straight, smooth restriction tube of definite diameter and length was placed in the piping to limit the amount of water each householder might withdraw. Presumably, the customer paid so much a month for a certain size tube, a greater amount for a larger one. Thus, although flow metering as we know it today began sixty years ago, the rudiments, at least, were recognized nearly 2000 years ago.

Today, the successful use of Venturi tubes, and of other primary devices, requires a sensitive instrument for measuring accurately small changes in pressure differences, even when static pressures are high. The familiar mercury-filled U-tube manometer has undergone vast improvements (Fig. 1). Today, the level of the mercury is no longer observed through glass walls: Instead, a metallic float follows the level of the mercury in the larger chamber. The use of chambers with two different diameters reduces the travel of the float so that its position

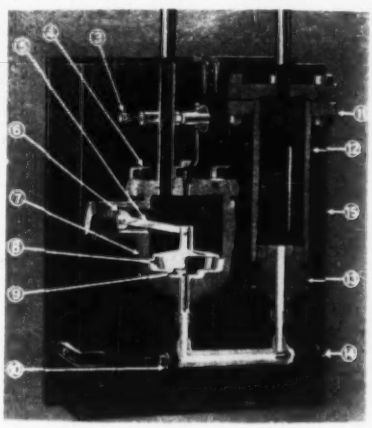


Fig. 1

may be readily transmitted outside the pressure casing through a system of levers and shafts. A seal is made around the main transmission shaft by a precision lapped bearing of stainless steel; or magnetic couplings do away with the need of stuffing-boxes, etc., for sealing shafts. In its present form, the float type manometer is widely used in industry. For many applications, it is doubtful indeed if any other mechanism will ever take its place. Still, it does have limitations.

The float type manometer doesn't lend itself readily to use aboard aircraft where the instrument may be subjected to forces of a lateral type which tend to drive the float against the case or its guide rods. The float type manometer may be made portable but it must be leveled precisely to obtain accurate results. Moreover, the weight of the mercury alone makes a lightweight unit difficult to produce. If an excessive differential pressure is applied, the mercury may be blown out of the instrument and lost. Even though check valves and mercury catch-pots have been devised to prevent or reduce these losses, mercury consumption is still high. This is not only caused by over-ranging, but by the activities of the mercury thief as well. A float type recorder contains enough mercury to make an evening's work for the thief quite profitable.

These problems are only annoyances, however. The primary reason that other means of differential pressure measurement have been sought stem from something more basic. Mercury forms explosive compounds with common chemicals such as ammonia. Apparently, the compounds are stable at high pressures and break down only when disturbed after the pressure has been released. The float type meter may be safe enough when in service but may become a "booby trap" for the unwary repair man.

The photographic industry demands chemicals that are produced without contact with mercury. The liquid metal, even if present in only minute quantities, will fog photographic emulsions just as readily as light, x-rays, or nuclear reactions. Consequently, flow meters containing mercury can't be used in plants producing solvents used to make acetate film, for example.

Some of the organic sulphur compounds act as emulsifying agents for mercury and petroleum. When the specific gravity of the mercury column in a float type meter is altered by emulsification, the calibration is changed

* Presented before the Southern California Meter Association.

FEBRUARY MEETING
"HI-JINKS"

Saturday the 18th, Rio Hondo Country Club, Downey, Calif. Dinner at 6; festivities until 11 p.m. Non-members cordially invited.

THERON S. CODY
Publicity Chairman

Correction: Paul RENFREW (not Renfro) is the name of the January speaker. Sorry we misspelled it in last month's meeting notice. —T.S.C.

radically. Such sulphur compounds are present in certain crude oils and gases. In these services the float type meter won't work without seals, which at best are a nuisance and may even produce erroneous readings if they're not properly handled.

Some of the limitations of the mercury float manometer are not present in a meter operating on the principle of the

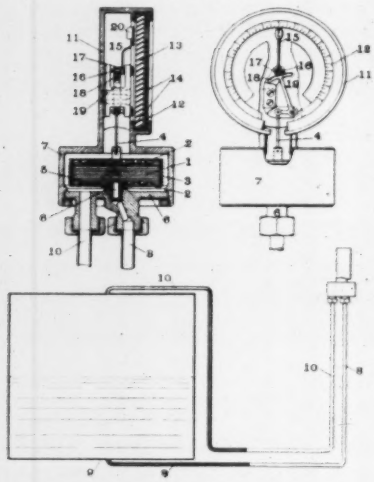


Fig. 2

deflection of a flexible metallic bellows. The bellows-actuated meter may be made quite compact. The size of the meter doesn't change appreciably with increases in differential pressure range. Changes in range may be made without replacing major parts. The bellows type meter doesn't require mercury or any other liquid to balance out the differential pressure, hence it may be made light and quite portable. The bellows type meter lends itself admirably to the use of a torque-tube instead of a pressure-tight bearing or stuffing-box for the transmission of bellows position to the indicating or controlling mechanism. This in turn, results in fewer service problems, especially in high-pressure gas measurement.

From a theoretical view, the bellows-actuated meter has certain positive advantages over a liquid-manometer type of meter. In commercial use, however, some definite problems are encountered. Commercially-available bellows were, for a number of years, not entirely suitable. Spring rates and effective areas weren't constant: variations in these two factors introduced complications in calibration, particularly when the bellows was to be replaced by the instrument user. The high degree of sensitivity of bellows type recording meters was a handicap in handling pulsating flows because the instrument response could not be readily damped.

By far the most serious problem was the protection of the bellows against damage if an excessive differential pressure should be accidentally imposed across the instrument. If the bellows was made sufficiently strong to withstand the full operating pressure imposed across it, the deflections for normal differentials required extensive magnification. This introduced the problem of combating friction if the magnification was done mechanically, as is the case in most industrial applications. A bellows capable of withstanding high internal pressure is more subject to hysteresis because of the geometrical relationship between bellows diameter and bellows metal thickness. As a compromise it was necessary to use a relatively fragile bellows and

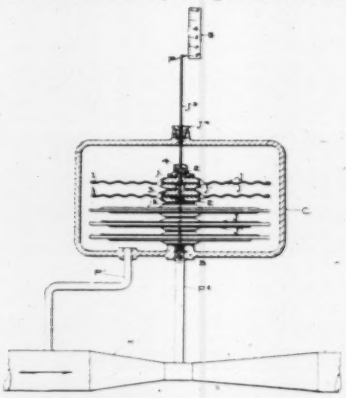


Fig. 3

depend upon relief devices or careful operating procedures to prevent bellows damage.

Flexible metallic bellows were proposed for use in pressure-measuring mechanisms shortly after the work of Venturi, but, unfortunately, practically no information has been handed down to us about these early devices. Eugene Bourdon, the capable Frenchman who is credited with inventing the static pressure element bearing his name, also patented a bellows-actuated aneroid barometer in 1852.

The United States patent office offers us the opportunity to take some interesting glimpses into the history of bellows-actuated differential pressure gages, and, incidentally, take a look at trends in the development of bellows manufacturing methods as well.

A patent was granted in 1901 for a bellows-actuated boiler water-level gage (Fig. 2). To overcome the problem of stuffing-box friction and leakage, the inventor simply enclosed the entire mechanism (movement, pointer, scale and all) inside a case with a glass cover. The higher pressure, represented by the steam pressure plus the liquid head in the condensing leg, was conducted to the outside of the bellows, while the lower pressure at the base of the boiler (produced by the steam pressure plus the liquid head in the boiler) was introduced inside the bellows. Although the inventor also mentioned the use of this gage as a method of measuring pressure drop across the valves, he seems to have been wholly unaware of its possibilities as a flow meter. This was unfortunate, because it would have worked admirably wi a Venturi tube as an indicator of w- pressure water flows. In fact, a- ou- five years ago, a manufacturer, pr- m- inent in the water-works field, pl- ced a gage on the market that oper- ted on this very principle.

The next patent, granted in 1911 (Fig. 3), is of interest because i- is the first one to describe a bellows type meter for use with a primary de-ice (in this case a Venturi tube) for m- as-uring flow rates. This inventor pro-posed the first system for preven-ing damage to the bellows as a resul- of

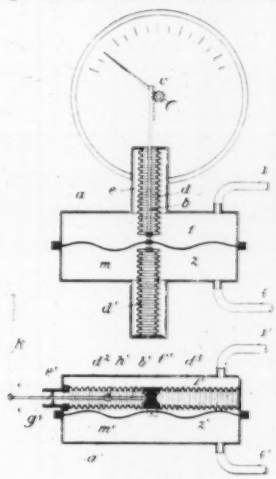


Fig. 4

excessive flow rates. The bellows was designed to compress with increasing differential pressure and the bellows convolutions were shaped to fit into one another and thereby prevent distortion, even if the assembly closed completely. The proposed method of transmitting bellows motion outside the pressure chambers was wholly unsatisfactory, and this may have led to the development of a mechanism patented in 1913, using a pair of bellows in conjunction with a flexible diaphragm (Fig. 4). The movement of the diaphragm and the bellows, upon application of pressure differences to chambers 1 and 2, was transmitted to the indicating mechanism through a rod connected to the inner end of one bellows. Because of the limitation imposed by the strength of the transmitting bellows, this unit could be used only for relatively low static pressures.

The second idea shown in Fig. 4 is an alternate method of combating the problem of pressure-bearing leakage and friction. The bellows assembly was to be bent by the flexing of the diaphragm. The rod b' passing through the bellows was pivoted at the fulcrum g'. Movement of the diaphragm would cause the outer end of the rod b' to move up and down. It is of interest to recognize that modified versions of this method of transmitting motion from within high-pressure vessels are being used today by two different manufacturers.

In 1928 a West Coast manufacturer patented and produced an instrument that was unique because it represented the first use of the torque-tube in conjunction with a bellows. This was really a significant innovation because, even though pressure-tight bearing construction had been improved by better techniques in lapping, these bearings still required lubrication. Lubricants that won't dissolve in certain petroleum products, for example some of the solvents, aren't completely satisfactory. In some industries, the lubricant may be slowly altered by chemical changes which effect lubricant viscosity with resultant increases in bearing friction. Moreover, there simply isn't a universal lubricant. With a torque-tube, all these problems disappear.

The construction and operation of a torque-tube as applied to instruments is familiar to most instrument users; nevertheless, let us review the device briefly. First of all, the torque-tube is a mechanism for transmitting rotary motion through the walls of a pressurized chamber without the use of stuffing-boxes or closely-fitted shafts and bushings. It consists of a thin-walled tube, rigidly attached at one end to the wall of the pressure chamber. Passing inside the tube and rigidly attached to its inner end, is a shaft. The shaft projects beyond the tube outside the pressure chamber. The inner end of the tube and the outer end of the shaft are supported on suitable bearings.

When the inner end of the tube and shaft assembly is rotated, the thin-walled tube twists because its other end is firmly anchored into the pressure chamber wall. The outer end of the shaft, being freely suspended, turns through the same angle as the inner end of the tube. In this way, the rotary motion imparted to the inner end of the torque-tube assembly also appears on the outer end of the shaft. At the same time, fluid pressure applied to the inner end is completely and positively sealed without any chance of leakage.

The first instrument to incorporate this torque-tube had built-in over-range protection in the form of a thin soft-metal plug mounted in an auxiliary bellows separating the high and low-pressure chambers, and was provided with a mechanism which punctured the plug when the differential pressure became too great. After the instrument had been over-ranged, it was necessary to replace the safety plug before it could be put into service again. This system of over-range protection was positive because there were no valves to stick; but it, too, became ineffective when called upon to protect the bellows against extremely high differential pressures.

In 1941, at the request of certain chemical companies, another manufacturer developed the bellows-type flow meter shown in Fig. 5. It was outstanding because, for the first time, a stainless steel bellows was used. Although it didn't contain a relief device, the use of a torque-tube made it somewhat similar to the unit that appeared in 1928. Differential pressure range was determined by the torque-tube strength rather than by a calibrating spring. Even though it was subject to the problem of bellows damage as a result of excessive differential pressures, this instrument made important contributions to the war effort, in atomic energy work, and in the HF Alkylation plants designed to produce 100-octane aviation gasoline.

During the war a special submarine gage was required to measure differential pressures that were of essentially the same magnitude as the static pressure. To simplify the unit by avoiding the use of a pressure bearing or torque-tube, a dual bellows design was selected (Fig. 6). The closed ends of the two bellows were jointed by a stem, from which the indicating mechanism took its motion. The two pressures, whose difference was to be measured, were introduced into the bellows.

Now this gage wasn't particularly important as a product, but it was important as the germ of an idea. As we've mentioned before, the innumerable attempts to design automatic valve arrangements to protect the bellows mechanism were unsatisfactory for one reason or another. The submarine gage started a new train of thought (Fig. 7). Suppose we were to turn this double bellows affair inside out; put the line fluid on the outside and retain the center stem holding the two bellows ends together. This center stem would pass through a plate on which the bellows could be mounted. Likewise, the stem would bear two valves, one of which would close against the center plate when the bellows were displaced beyond the normal travel in either direction. Now let's completely fill the inside of the bellows with a clean non-corrosive liquid. When the bellows is shifted as a differential pressure is applied, this liquid must travel from one bellows chamber to the other through the annular space between the bellows

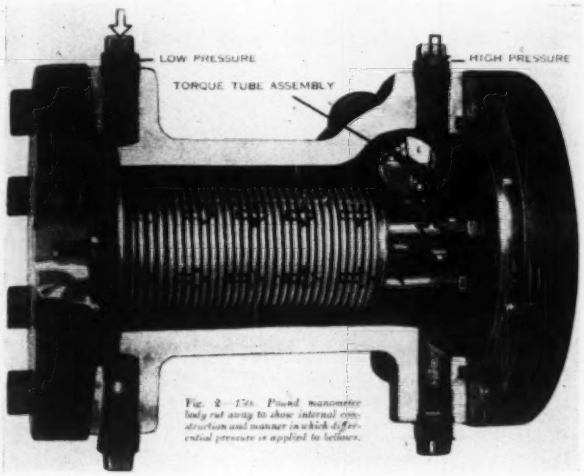


Fig. 5

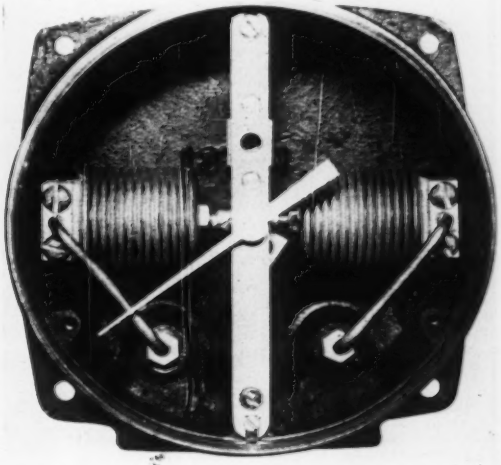


Fig. 6

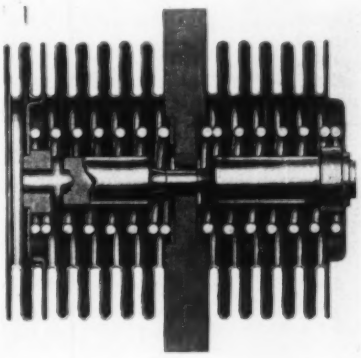


Fig. 7

center plate and the bellows stem. When the maximum bellows travel has been reached, one valve closes and liquid may no longer flow from one chamber to the other. Because the liquid may not escape, the bellows will not be destroyed by the imposition of additional differential pressure.

A simple way to lick the over-range problem, isn't it?—and just as effective as it is simple! The valves always close because they are in a clean liquid; they are free-floating and therefore cannot bind or stick.

Although this looked like the answer to the question of bellows damage, there were still some problems to solve. Experiments with an early model revealed that changes in fill-fluid volume as the result of ambient temperature variations would cause appreciable shifts in zero reading. With the dual bellows construction, the entire assembly would shift in the direction of the larger bellows when the internal pressure increased. Furthermore, the change in bellows diaphragm shape altered the spring rate, resulting in changes of differential range.

These difficulties were corrected by incorporating a chamber whose volume would increase or decrease readily without major changes of internal pressure. The temperature compensator was added beyond the bellows end-plate on the high-pressure side of the assembly. A hole in the inner end-plate permitted the passage of fill-fluid into or out of the floating bellows. Thus, as the liquid expanded, the compensator bellows changed shape to accommodate the additional volume. True, the internal pressure in the bellows increased a trifle, but the effect was negligible compared to the pressures built up in the original design. Fig. 8 is a cross-section through the first instrument made (1943) using the temperature-compensated rupture-proof bellows construction.

To utilize all the advantages of rupture-proof bellows design, a torque-tube, together with stainless-steel construction, was incorporated in 1948. As an additional advantage, the calibration spring was located outside the bellows assembly in the low-pressure housing where it could be reached easily when a change in range was to be made.

It is important to recognize that the torque-tube was placed inside the bellows assembly where it is always in contact with a controlled fluid. Such construction makes it practical to mount the torque-tube on needle bearings while the movement of the bellows is transferred to the follower arm through a miniature ball-bearing. That this construction results in a high degree of sensitivity is demonstrated by the fact that pointer motion may be observed with a change in differential pressure of only one part in 4000 at high-pressure levels, currently up to 3000 psi. This means that changes in pressure differential of 0.025 in. water column will result in pointer travel in an instrument calibrated for 100 in. W.C. Naturally, a magnifying glass is necessary to observe the pointer movement, but it actually is discernible.

Commercially-available bellows didn't make possible full use of the potential advantages of the rupture-proof construction. Actually, a bellows of paper-thin metal was required; in fact, within limits, the thinner the better. At the same time, a fairly large bellows was desired in order to supply ample power to drive recording and controlling mechanisms.

Because a bellows is, after all, a special form of spring, the characteristics of the metal should approach those of spring steel as nearly as possible. To produce efficient bellows forms, it is necessary to draw the raw sheet stock into fairly complex shapes. This precludes the use of spring-temper raw materials.

Even though commercial methods had been developed for assembling stainless-steel diaphragms into bellows using the helium arc welding process or the atomic hydrogen process, there were two objections. The thinnest material that could be assembled was far too thick for a suitable bellows; furthermore, the welding seriously altered the temper of the metal at the location of the weld. To produce bellows with the desired characteristics, an unusual seam-welder was developed to weld the 0.003-in. thick diaphragms into completed bellows, and also weld the bellows to heavier end fittings (Fig. 9).

Bellows-actuated flow meters are used for the same applications as the mercury float type manometers; that is to say, flow measurement of liquids and gases in a myriad industries extending from swimming pools to atomic energy plants. However, the meters employing the rupture-proof bellows principle are suitable for certain unique jobs.

If the low-pressure housing of the gage is left open to atmosphere and the high-pressure side connected to a highly-variable pressure, the unit is capable of acting as a low-pressure gage with over-range protection. In some industrial and naval applications, it is essential to measure low pressures quite accurately, which dictates a unit with low range; however, the pressure will often rise to high levels. The use of the rupture-proof construction makes it unnecessary to disconnect the low-pressure gage when higher pressures are present.

A similar application is found in pressure switches which must withstand high normal pressures and yet open or close when the system pressure approaches atmospheric pressure. The rupture-proof principle makes such switches quite simple and absolutely reliable. With the more commonly used Bourdon-tube-actuated switches, it's difficult to maintain the trip pressure under such operating conditions. The tubes have an accuracy of about 1 percent of full range; if the normal pressure is 1000 psi. and the unit is to trip at 15 psi., the basic accuracy of 1 percent or 10 psi. makes this a bit difficult. The switch might trip at 25

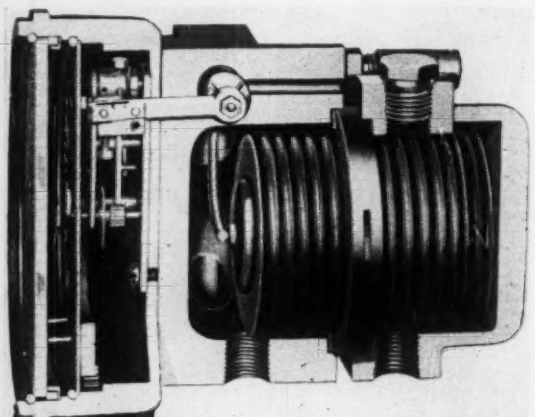


Fig. 8

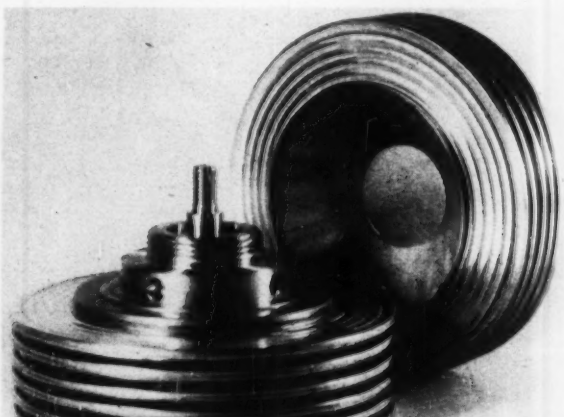


Fig. 9

psi. or it might trip at 5 psi. On the other hand, a rupture-proof bellows actuated switch would trip between 14.8 and 15.2 psi.

Occasionally it may be necessary to measure pressures at high levels with a degree of accuracy beyond that of a pressure gage. This may be done readily by using a rupture-proof bellows-actuated indicator and a dead-weight tester. Now the tester normally has an accuracy of 0.1 percent of the pressure being measured, whereas, for comparison, a good pressure gage has an accuracy of 0.5 percent of its full range. The rupture-proof bellows-actuated differential pressure indicator is installed between the pressure to be measured and the dead-weight tester. Therefore, it measures the difference between the two. Because the indicator, with a low differential range, has a degree of accuracy that is high compared with the system pressure, it is possible to obtain accurate pressure measurements at unusually high pressure levels. The use of the rupture-proof indicator prevents the accidental release of system pressure that would almost certainly occur if the dead-weight tester were employed alone.

A rupture-proof bellows type differential pressure indicator is commonly used as a gage for level measurement of refrigerated liquified gases such as CO_2. Essentially it's a boiler level gage operating in reverse. An uninsulated piece of pipe, horizontally located at the bottom of the tank, acts as a vapor generator. The generator supplies gas to the high-pressure side of the indicator while the top of the tank is piped to the low-pressure side. The entry of liquid into the gage and small piping is prevented by the constant supply of CO_2 gas that is available from the generator to increase the pressure in the piping and instrument when the liquid level increases.

Naturally, the outstanding advantage of a meter that is not damaged by over-range lies in the fact that the instrument will not be harmed if an operator accidentally opens the valve that vents one side of the instrument to atmosphere, or similarly, if the block valves are opened incorrectly when the instrument is being placed in service. With a rupture-proof bellows-actuated flow meter, it is quite permissable, when placing the unit in service, to open one block valve with the by-pass valve closed, even though the instrument may be connected to a system with line pressures of 1000, 2000, or even 3000 psi.

To test the efficiency of the rupture-proof bellows design, one company, prominent in the oil and chemical field, connected a rupture-proof bellows-actuated indicator across the discharge outlets of a double-acting reciprocating pump. The instrument was installed in such a way that each time the pump stroked, 1500 psi. was applied to one chamber and approximately 1200 psi. to the other. With each reversal of the pump piston, the pressures were applied to alternate chambers on the meter. The instrument calibration was 25 in. W.C. or approximately 1 psi. In other words, the over-range differential pressure applied to the instrument was 300 times its normal range. The plunger of the pump stroked approximately 20 to 25 times per minute, and the tests were continued for 20 days. The net result was an application of an excessive differential pressure (alternately in the normal direction of differential and then in the opposite direction) approximately half a million times. At the conclusion of this test, neither the instrument's calibration nor its zero was appreciably altered. In fact, the instrument is still being used in the experimental department of the company which conducted these tests.

Because a rupture-proof bellows-actuated flow meter is automatically self-draining, the seal pots sometimes used when wet gas is being measured aren't necessary. Any liquid that may condense inside the meter chamber will automatically drain out of the instrument housing because the fluid being measured only contacts the outside of the two sets of bellows. Similarly, if a rupture-proof bellows-actuated flow meter is used on a gas line where there may be intermittent surges of liquid, any liquid that may rise into the bellows chambers will drain out completely and automatically. At the same time, the differential pressure created by the passage of liquid through the orifice instead of gas won't damage the instrument in any way.

Of interest too, is the ease of installation of the bellows type meter. The instrument need not be leveled precisely; in fact, it would function upside down if there were a need for such a novel installation. Of course, there's no need to fill the unit with mercury: merely pipe it up and it's ready for use.

Whenever bellows type recording meters were employed in the past for industrial applications where pulsating differential pressures were encountered, they were found to be unsatisfactory. Indicating instruments could be used on slowly pulsating services without difficulty, but this was not true of recording meters. Even non-periodic pulsations with a time interval of two minutes between pulses would produce a broad trace on the chart. More rapid changes would form ink blots as well as cause rapid ink depletion.

This trouble plagued the rupture-proof bellows construction just as with the older single-bellows style, even though the former design provided a degree of inherent damping. The bellows fill-fluid, in flowing from one bellows chamber to the other, reduced the instrument's response rate. In 1949 an internal, completely adjustable pulsation dampener was included in the basic rupture-proof bellows design. The annular restriction between the two bellows chambers was drastically reduced by the introduction of a floating piston ring on the bellows center stem within the center plate (Fig. 7). The flow of fluid between the two chambers as a differential pressure was applied was, thereby, greatly slowed down. To provide for adjustment to operating conditions, an O-ring-sealed adjustable needle valve by-pass around the piston ring was supplied. Instrument responsiveness could be selected from ten seconds to five minutes for full-scale travel. The selection could be made while the instrument was in service and under pressure. There could be no danger of unequal snubbing of the meter as could be done with two external line dampeners; the dampener valve and mechanism never contacts the line fluid, so it will operate in a trouble-free manner with no plugging or sticking.

With the addition of the internal adjustable pulsation damper to the earlier developments of the torque-tube and rupture-proof bellows construction, differential-pressure-measuring apparatus is now available that not only offers all the inherent advantages of bellows type meters but also provides the desirable features of mercury-float type instruments without the service problems that are inextricably linked with them.

We've talked of the early as well as the recent developments in a phase of the new science and engineering born sixty years ago. It will surely be forgiven if we attempt a fleeting glance at the future. To do so requires the turning of more pages in history. A few years before the development by Herschel of the Venturi tube, Clerk Maxwell published the first comprehensive paper on feedback mechanisms as related to steam engine governors. You will recall that most of the modern control devices are built around the basic principle of feedback. Thus, at roughly the same time, the beginnings of control mechanisms, as well as a phase of measuring mechanisms, had their inceptions. It's fundamental that *before a condition can be controlled it must be measured.*[2] Therefore measuring and controlling devices are closely linked.

About eighteen years ago it became increasingly clear that the mechanisms of control developed by man and the mechanisms of control within man are remarkably similar. The phenomenom known to the instrument engineer as "hunting" is closely related to what the physician calls clonic contractions in the epileptic patient. Complex calculating machines go through a process of "learning" over a period of operating time and, if subjected to conflicting impulses, may break down and react as an insane person does; moreover, the "cure" for such calculating mechanism insanity is shock—the same as in the human being. This may be interesting enough, you say, but what has it to do with Flow Meters? No doubt about it, the connection isn't concrete—we are just looking ahead in a broad way.

Man is now able to produce control mechanisms capable of performing the functions once reserved for the human

[2] "Fundamentals of Instrumentation" (1932).

mind. The aircraft fire control computers developed a quarter-century ago are outstandingly superior to the manually-operated devices; and those developed during World War II are even more efficient. Refineries are capable of making products requiring a degree of control that would be entirely impossible using the hand control methods of thirty years ago. Indeed, during the past ten years the refinery has become a "manless plant." Year by year the evidence grows to show that the *completely* automatic factory for mass production of standardized products is not far away. What changes may such skills and knowledge make in the economy of tomorrow's world?

A few generations ago, the world experienced the industrial revolution when machinery replaced man's muscles to provide the power in manufacturing goods. There appears to be evidence that a second industrial revolution is in the making as the result of man's potential ability to produce automatic-control systems capable of doing routine "thinking." The changes in the world of our children and grandchildren may well be as powerful as the effect James Watt's steam engine had on the generations succeeding his day.

TECHNICAL SOCIETIES

Society for Applied Spectroscopy

February meeting, Tuesday the 7th. Informal dinner, 6 p.m. at Tosca's, 118 Fulton St., New York City. Reservations are not necessary. Meeting, 8 p.m. at Socony Vacuum Training Center, 63 Park Row, New York City. Contributed Papers by Society Members:

"Three-line Method of Heterochromous Photometry" by Dr. Milton Green, Squier Signal Laboratory.

"Spectrochemical Analysis of Lead and Zinc in Ores" by Isidore Adler, U. S. Customs Laboratory.

"Rapid Identification of Plastics by Infrared Absorption Means" by Harry Hausdorff, General Cable Corp.

"Investigation of Kodak I-N and I-L Spectroscopic Plates" by R. Hoffman, Socony Vacuum.

"Spectrochemical Determination of Magnesium in Low Alloy Steel" by Neil Gordon, International Nickel Co.

—RODGER W. LOOFBOUROW

The Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy and Exposition of Modern Laboratory Equipment.

Sponsored by: Analytical Division, Pittsburgh Section, A.C.S. and Spectroscopy Society of Pittsburgh.

William Penn Hotel,
February 15-17, 1950

TENTATIVE PROGRAM

Wednesday morning. C. Manning Davis presiding.

Welcoming Remarks: R. A. Friedel, Chairman, Spectroscopy Society of Pittsburgh; T. C. Bryson, President, Analytical Division, Pittsburgh Section, A.C.S.; Mary E. Warga, University of Pittsburgh; Henry Freiser, Chairman of Exposition.

Philip J. Elving, The Pennsylvania State College, "The Fundamental Operations of Analytical Chemistry"

George R. Harrison, Massachusetts Institute of Technology, "Progress in Spectrographic Instruments."

Afternoon Session, R. G. Russell presiding.

William Seaman, American Cyanamid Co., "The Industrial Analytical Chemist in a Changing Scene."

J. Convey, Canadian Bureau of Mines, "Spectro Chemistry at the Bureau of Mines in Ottawa."

Chester M. Alter, Boston University, "An Analysis of Analyses."

Van Zandt Williams, Perkin-Elmer Corp., "Recent Developments in Infrared Spectrometry".

Wednesday evening. Conference Dinner, Toastmaster, J. R. Anderson; Main Speaker, H. V. Churchill.

Thursday morning. Henry Freiser presiding.

Harvey Diehl, Iowa State College, "Titrations With Ethylenediaminetetraacetic Acid."

H. H. Willard, University of Michigan, "The Determination of Fluoride."

George A. Perley, Leeds & Northrup Co., "Electrode Problems in Electrometric Measurements."

E. St. Clair Gantz, Gerald C. Whitnack, Clifford J. Holford, G. B. L. Smith, U. S. Naval Ordnance Test Station, China Lake, Calif. "Determination of Nitric Oxide and Nitrogen Dioxide in Admixture."

Thursday afternoon. M. L. Moss presiding.

C. F. Hiskey, Polytechnic Institute of Brooklyn, "Colorimetry Applied to High Absorbance Systems."

H. A. Liebhafsky, General Electric Co., "Some Unusual Cases in Photometric Analysis."

George Telep and D. F. Boltz, Wayne University, "Ultraviolet Spectrophotometric Determination of Molybdenum."

R. E. Kitson, E. I. du Pont de Nemours & Co., "The Simultaneous Determination of Cobalt, Copper, and Iron."

H. F. Beeghly, Jones and Laughlin Steel Corp., "The Behavior of Nitrogen and Some of Its Compounds in Steel"

P. E. Wenger, D. Monnier, Y. Rusani, University of Geneva, "The Use of Sensitive Reactions in Semi-Quantitative Determinations" (Translated and presented by Henry Freiser)

Thursday morning. J. J. McGovern presiding.

X. D. Cogqeshall, Gulf Research and Development Corp., "Determination of Organic Functionality by Molecular Spectroscopy"

C. W. Young, M. R. Meeks, V. E. Whittier, Dow Chemical Co., "Some Considerations on the Determination of Low Molecular Weight Polar Solutes in Non-Polar Solvents"

John U. White, Perkin-Elmer Corp., "Applications of a Double Beam Infrared Spectrophotometer"

D. D. Friel, E. I. du Pont de Nemours & Co., "Analysis of Plant Samples with Infrared Gas Analyzers"

James D. Stroupe, Rohm and Haas Co., "Infrared Analysis of Certain C_1-C_5 Hydrocarbon Mixtures"

Thursday Afternoon. F. A. Miller presiding

J. S. Ard, Thomas D. Fontaine, U. S. Department of Agriculture, "Triethylamine Addition as a Means of Increasing the Applicability of Infrared-transmitting Solvents"

H. G. Monteith, Aluminum Research Laboratories, "Quantitative Infrared Analysis of Solid Isomeric Mixtures."

J. Seidman, Sinclair Refining Co., "Infrared Analysis of Cis- and Trans-Decalin"

R. A. Friedel, U. S. Bureau of Mines, "Infrared and Ultraviolet Spectra of Phenols"

Thursday morning. J. R. Churchill presiding.

M. F. Hasler, Applied Research Laboratories, "The Direct-Reading Analysis of Stainless and Tool Steels Covering Wide Ranges of Composition"

R. W. Callon, L. P. Charette, Aluminium Laboratories Limited, "Direct Reading Methods for Analysis of Aluminium and Aluminium Alloys Using Pin Samples"

George Wiener, Westinghouse Electric Corp., "The Effect of Heat Treatment and Composition on the Spectrographic Determination of Carbon in Steel"

Galen Porter, Union Carbide and Carbon Research Laboratories, "The Spectrochemical Determination of Magnesium in Cast Iron"

W. B. McCreary, International Harvester Co., "Factors Influencing the Spectrographic Analysis of Silicon in Gray Iron"

Thursday evening. G. W. Kelch presiding

Grant T. Wernimont, Eastman Kodak Company, "Design and Interpretation of [illegible] Factor Experiments

This session will be followed by an informal social hour.

Friday morning. R. A. Friedel presiding

Lionel S. Goldring, Roland C. Hawes, Arnold O. Beckman, Charles D. Coryell, Michael E. Stickney, National Technical Laboratories, "Anomalies in Extinction Coefficients at Low Absorbancies"

D. L. Timma, Mound Laboratory, "A Modified Beckman Spectrophotometer and its Performance"

J. R. Anderson, J. J. McGovern, Mellon Institute, "Spectrophotometric Detection and Determination of Thianaphthene in Naphthalene"

J. E. Newell, U. S. Rubber Co., "Residual Monomer in Polystyrene—A Spectrophotometric Method"

Alvin S. Glessner, Jr., A. C. Whitaker, N. E. Coggeshall, Gulf Research and Development Corp., "Ultraviolet Absorption Analysis for N, N'-di-sec-butyl p-phenylenediamine in Gasolines."

Frank P. Hazlett, Roy B. Hannan, Jr., Joseph H. Wells, Mellon Institute, "Determination of Anthracene in Crude Anthracene Cakes by Ultraviolet Spectrophotometry."

Friday morning. Mary E. Warga presiding

B. F. Scribner, National Bureau of Standards "Standardization of Spectrographic Analytical Methods"

J. Sherman, Philadelphia Naval Shipyard "Stability of Spectra as Determinable by Statistical Analysis of Experimental Data"

John Harley, George Peterson, George Welford, U. S. Atomic Energy Commission, "Spectrographic Determination of Beryllium in Air Dust Samples"

E. K. Jaycox, Bell Telephone Laboratories, "The Quantitative Spectrochemical Analysis of Ashes, Deposits, Liquids, and Other Miscellaneous Samples"

J. T. Rozsa, N. A. Grondin, J. Golland National Spectrographic Laboratories, Inc. "Crucible Fusion Techniques of Spectrographic Semi-Quantitative Analysis"

Alfred T. Myers, U. S. Geological Survey, "An Improved Cutting Tool for Spectroscopic Electrodes"

B. F. Scribner, J. C. Ballinger, National Bureau of Standards, "Spectrochemical Analysis of Bronzes by the Porous Electrode Technique."

J. A. Norris, Massachusetts Institute of Technology, "Spectrographic Analysis of Beryllium Metal"

Friday afternoon. J. C. Redmond presiding

W. A. Kirklin, Hercules Powder Co. "Standardization in Analytical Chemistry"

Calvin Golumbic, Bureau of Mines, "The Separation and Analysis of Phenols by Countercurrent Distribution"

L. A. Wooten, W. G. Galdner, Bell Telephone Laboratories, Inc., "Low Pressure Techniques The Determination of Oxygen and Carbon in Metals"

E. B. Read, L. P. Zopatti, Massachusetts Institute of Technology, "The Determination of Oxygen in Zirconium Metal"

L. C. Copeland, F. S. Griffith, The New Jersey Zinc Co., of Pa., "The Manual Polarograph for Rapid Routine Determinations—Lead and Cadmium in Zinc"

Willard P. Tyler, Earl C. Gregg, The B. F. Goodrich Research Center, "An Analytical Polarographic Study of the Bis (Dialkylthiocarbamyl) Disulfides and Dialkyldithiocarbamates"

Allen M. Goldstein, Tracerlab Incorporated "Some Uses of Tracer Techniques in Analytical Chemistry"

Friday afternoon. J. H. Lieblich presiding

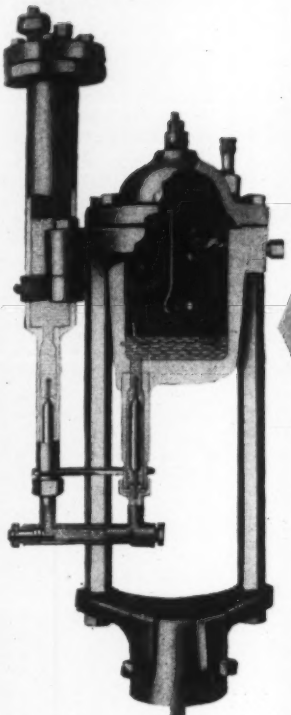
Harold P. Klug, Mellon Institute, "Recent Applications of X-Ray Diffraction in the Analytical Field"

William Priestly, Jr., Esso Laboratories, "Fluorescence Spectroscopy"

Anne L. Conrad, Winifred C. Johnson, Standard Oil Co. of Ohio, "Flame Photometer Techniques for Determining Typical Additives in Petroleum Oils"

Richard H. Hughes, Westinghouse Research Laboratories, "Microwave Spectroscopy and Chemical Analysis"

FINAL NOTICE
of Instrumentation Contest
See Page 94



Proper float location gives you EXTRA METER VALUE

HERE'S HOW TEMPERATURE ERRORS ARE CANCELED

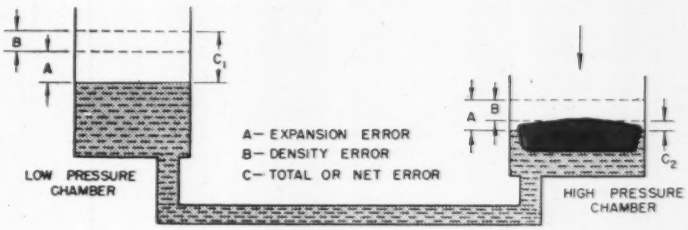
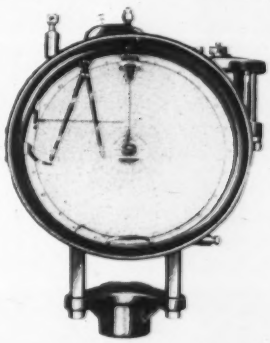


Diagram shows two distinct ambient temperature error factors (exaggerated for clarity) which affect the accuracy of mercury displacement type flow meters. On an increase in temperature, for example, the mercury expands and its level rises an equal amount (A) in both high and low pressure chambers. Mercury density also decreases because of the same increase in temperature, resulting in increased displacement (B) for a given differential pressure change. This increased displacement adds to error (A) in the low pressure chamber, causing a combined error C_1 — but *subtracts* from error (A) in the high pressure chamber, leaving only a negligible net error (C_2).

Better Design Throughout Assures Greater Accuracy with Foxboro Meters

Engineering thoroughness in every detail throughout Foxboro Flow Meters demonstrates conclusively why you get *extra meter value*. Locating the meter float in the high-pressure chamber is only one of many examples. Based on broader understanding of basic principles, this simple design feature utilizes two inherent sources of thermal error to offset each other. The result is highest sustained accuracy through the range of the instrument, regardless of temperature variations.

Even for your simple installations, you'll save money in the long run by employing Foxboro Meters. Write for Bulletin 351-2 describing these extra-values. **The Foxboro Company, 60 Neponset Avenue, Foxboro, Mass., U. S. A.** Branches in 32 U. S. cities—also 6 Canadian cities.



EXCLUSIVE FOXBORO REFINEMENTS

- Segmental Lever Transmission gives *truly* straight-line calibration.
- Extra-large Float with long travel gives extra power.
- Sure-Seal Check Valves, submerged in mercury, positively prevent mercury losses from overrange.
- Pressur-Tite Frictionless Bearing eliminates stuffing box and packing.

FOXBORO REG. U. S. PAT. OFF. **DIFFERENTIAL-TYPE FLOW METERS**

a + value for industry

Development and Production of

SPECIAL PURPOSE VACUUM TUBES

BY ECLIPSE-PIONEER

We're not in the standard vacuum tube business. But we are definitely in the business of developing and manufacturing special purpose vacuum tubes—tubes that are not generally available. During the past three years, for example, our facilities have produced, such devices as the Chronotron thermal time delay tube, the Convectron* vertical sensing tube, the TT-1 3000 mc temperature limited noise diode tube, counter tubes, glass enclosed spark gaps, and phono pickup tubes. Quantities of all these are now serving many phases of industry in a wide variety of applications. We invite your use of our facilities to develop and produce your requirements of special purpose vacuum tubes. Your inquiries concerning the scope of our facilities or details of any of our tubes will be given immediate attention.

TT-1 3000 mc Temperature Limited Noise Diode Tube.

Y-Type Position Convectron—Vertical Sensing Tube.

Chronotron Thermal Time Delay Tube.

*REG. U. S. PAT. OFF.

Eclipse-Pioneer Division of
TETERBORO, NEW JERSEY
Bendix AVIATION CORPORATION
Export Sales—Bendix International Division, 72 Fifth Avenue, New York 11, N. Y.

Regulation of pH

Continued from page 38

requiring large pumps, there may be objections to this system especially if costs of circulating unused reagent are considered important. In such cases, it has not been uncommon practice to replace the overflow loop with a level controller, as illustrated in Fig. 83, which throttles the pumping load to exact process requirements.

The effective flow capacity of the control valve varies as the square root of hydrostatic head of reagent above, and variations in elevation of the head box affect the valve rating. There is no important limitation to maximum elevation of the head box except cost of piping and handling equipment and pumping or transportation costs. However, the higher the head tank, the smaller must be the control valve for a given concentration of reagent. As would be expected, however, increased elevation can be compensated for a fixed valve size, by decreased reagent concentration, or, conversely, decreasing elevation requires increased concentration in a square-root ratio.

A lower limit to elevation of head box is established by practical operating conditions. In many cases, the box has been placed at a one-foot or two-foot elevation to compensate for an otherwise oversized valve, and in some cases connected to the valve through a long connecting pipe. This has not been found by the writer to be good practice since, aside from the evils of an oversized valve, the box may be displaced horizontally from the valve, and friction of connecting piping limits pressure drop across the control valve to a small portion of the total at open-valve positions. It does not respond with positive action and lacks control characteristics normally inherent when it commands the major portion of pressure drop in the feed system.

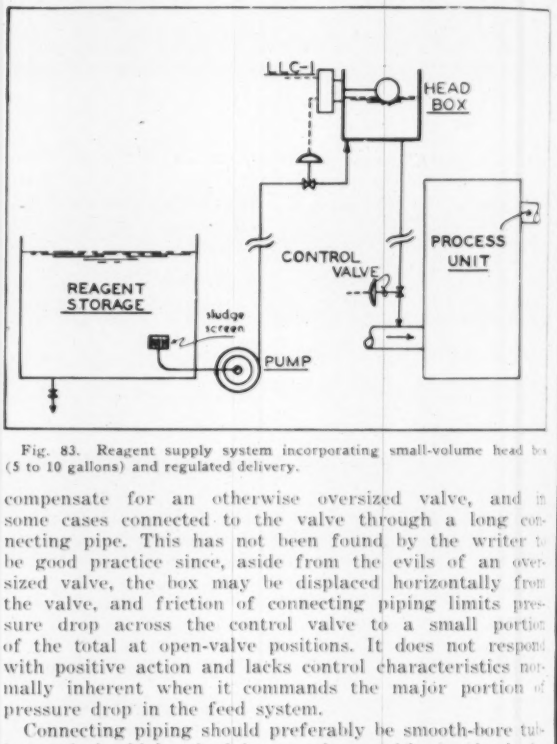


Fig. 83. Reagent supply system incorporating small-volume head box (5 to 10 gallons) and regulated delivery.

Connecting piping should preferably be smooth-bore tubing and should be sized in accordance with standard piping tables to allow no less than 50 percent of the total pressure drop across the valve. A minimum size of half-inch is usually recommended for small flows and the valve body is limited to this minimum size. Commercial air-operated valves are adaptable to adjustment for smaller flows of some reagents by means of variable size trim in a standard half-inch body.

The minimum head may be a matter of choice with engineers depending on plant conditions and piping costs although the writer has established, where possible, a minimum of 4.0 ft. and preferably 6.0 ft. for short connected installations. If the horizontal displacement is 2 ft. or more, an empirical minimum of 10 ft. hydrostatic head has been adopted. Volume of the head box may vary with applications, but average control installations require a head box no larger than 5 to 10 gallons capacity.

One might ask: "Why use a head box and why use a valve? A pump is necessary to distribute reagent, so why not use a controllable pump to feed reagent directly to the process from the reagent storage? Why pay for the

(A Quick Quiz on modern pH advancements)

Do you know these important facts about BECKMAN pH CONTROL?

Do you know...

That Beckman pioneered modern glass electrode pH equipment?

Until Beckman pH instruments were developed, glass electrode pH equipment was a cumbersome, complicated laboratory curiosity. It was Beckman that pioneered today's simple, compact, highly accurate and completely dependable glass electrode pH equipment!

That Beckman pioneered virtually every major development in modern glass electrode pH equipment?

Such far-reaching advancements as the High pH Glass Electrode . . . the High Temperature Glass Electrode . . . the Unusually Rugged "X-9" Glass Electrode . . . as well as a wide range of other vitally important advancements in glass electrode pH instrumentation, were *all* pioneered by Beckman. *Many of these advancements are still available exclusively in Beckman equipment!*

That Beckman offers the industry's most complete line of glass electrode pH instruments?

Included in the complete Beckman line are instruments specially designed to combine the high precision and wide versatility necessary for advanced research, medical and laboratory applications . . . others that combine maximum simplicity and high accuracy with complete portability for plant and field applications . . . still others that combine maximum simplicity and high accuracy with the plug-in convenience of full AC operation . . . plus *completely automatic* pH equipment for continuous pH indication, recording and control on large-scale processing applications.

That Beckman also provides the industry's most complete line of modern glass electrodes?

Although glass electrode pH instruments are the most efficient pH equipment obtainable, no glass electrode pH instrument is better than the versatility, accuracy and dependability of the electrode assemblies available for use with it.

Beckman provides the industry's most complete line of glass electrodes for use with Beckman pH instruments—a type of electrode assembly to meet every industrial, research, laboratory and field requirement!

That there are so many money-saving applications for Beckman pH control that you may be losing important profits unless you make a complete investigation of your operations?

There is pH wherever there's water, water solutions, moist pastes, sludges, slurries or other moisture-containing substances. And wherever there is pH, chances are the operation can be done better . . . with greater uniformity and less waste at lower overall cost . . . by Beckman-controlling the pH of the various processing operations.

WHETHER you manufacture food products or treat sewage . . . do metal plating or refine crude oil . . . make textiles or process ore — in fact, no matter WHAT *your field of operation . . . if you have not yet determined whether Beckman pH Control can be used to advantage in your operations — possibly is already* BEING *used to cut costs by your competitors — let us study your processes and make helpful recommendations. No obligation, of course.* BECKMAN INSTRUMENTS, NATIONAL TECHNICAL LABORATORIES, SOUTH PASADENA, 47, CALIFORNIA.

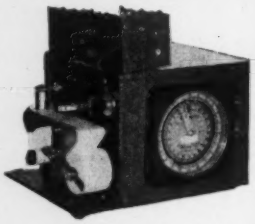
BECKMAN

For an informative, non-technical outline of modern pH control — what it is and how it's used — send for this free booklet "What Every Executive Should Know About pH."

INSTRUMENTS CONTROL MODERN INDUSTRIES

pH Meters and Electrodes — Spectrophotometers — Radiation Meters — Special Analytical Instruments

A RECORDING MECHANICAL COUNTER



Actuated by an Electrical Impulse

it operates on the output of a scaler, photo tube, or other electrical unit . . . permanently records counts on a 2¼" tape . . . automatically resets to zero.

In Radioactive Research it saves precious time by eliminating many hours of manual labor, resulting in greater economy and efficiency.

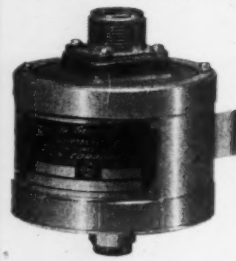
In industry it maintains a permanent record automatically, recording production and time each hour.

Write for complete information and illustrated circular SC 13.

STREETER-AMET COMPANY

AUTOMATIC WEIGHT RECORDERS & SCALES
HIGH SPEED COUNTERS SINCE 1888
4101 Ravenswood Ave., Chicago 13, Illinois

HIGH PROOF—To 400 PSI
LOW WORKING RANGE—From 0.1-100 PSI



PRESSURE ACTUATED SWITCH

MODEL 4101 Lightweight—Less Than 14 oz.

PRESSURE PORT

⅛ or ¼ Internal NPT Thread or
7/16-20 NF-3 PER AND10050 for Airborne Equipment

ELECTRICAL CONNECTOR

½ inch Conduit Connection or
AN 3102 Series for Airborne Equipment

Single pole double throw switching element suitable for AC and DC low current applications.

We are specialists in the design and manufacture of
AIRCRAFT • INDUSTRIAL • MARINE
PRESSURE ACTUATED SWITCHES

Write for descriptive literature

MELETRON CORPORATION
950 N. Highland Ave., Los Angeles 38, Calif.

installation of a head box?" This is a question which might be expected from any serious-minded engineer; it is a just question. Whether a head box or other feed device is used depends on cost requirements and plant limitations and pressure requirements of the feed device. A head box is limited to atmospheric pressure feed and is simple and fool-proof in operation but loses cost advantages when a large volume of reagent must be handled. It is recommended especially for plants having little modern facilities and untrained personnel for instrument maintenance and operation.

Direct feed of reagent by positive-displacement proportioning pumps is of particular importance when reagent must be injected into a pressure system. The writer has found a variable-stroke type quite satisfactory for injecting reagent into digesters and similar pressure vessels. Such pumps have also been used with success in water treatment and sewage disposal plants and have been especially well adapted to cascaded flow-pH installations

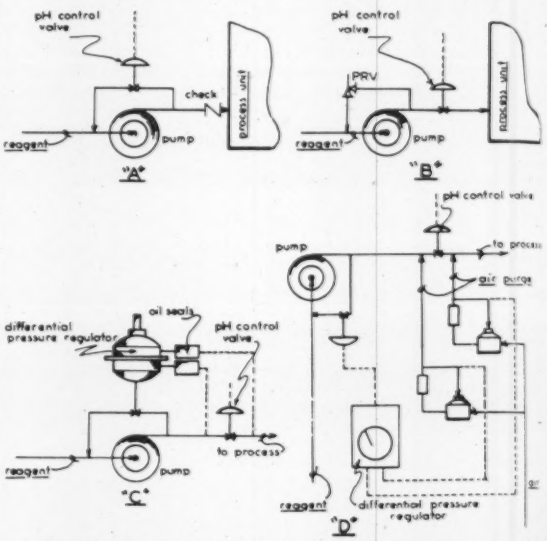


Fig. 84. Four accepted methods of maintaining constant pressure drop across pH control valve.

for controlling quiescent basins of high retention. They have the principal advantage that a head box and valve are not required and variations in supply pressure are without effect, if variations do not exceed a maximum or fall below a minimum limit. They are also especially well adapted to feeding small volumes of reagent.

The important advantage of smooth-acting control valves is their rapid response to fluctuating demands. They are generally preferred for direct high-rate neutralization reactions and processes having high buffer index and abrupt load swings. When properly applied, they effect an instantaneous transfer of reagent which is a *sine qua non* of good pH regulation. However, uniformity of flow characteristics (i.e. position *vs.* gpm. throughput) requires constant pressure drop across the valve at all positions; and, if gravity feed is not satisfactory or applicable, a number of methods may be, and have been, used successfully to maintain constant pressure drop as indicated in Fig. 84.

Fig. 84-A is a common method of applying the control valve as a by-pass around a constant-volume pump to regulate reagent feed. It is limited to positive pressure discharge and has the property of "reversing" effective valve characteristics. In other words, the effective flow of reagent to the process is a reciprocal characteristic of normally direct-connected valves. In some cases, this characteristic may be of importance to correct an otherwise effective narrow throttling range of a direct-connected valve.

Fig. 84-B has the advantage of wider turn-down and is applicable to both negative and positive pressure systems. Its principal weakness is the pressure relief valve which

Small AUTOMATIC Counters

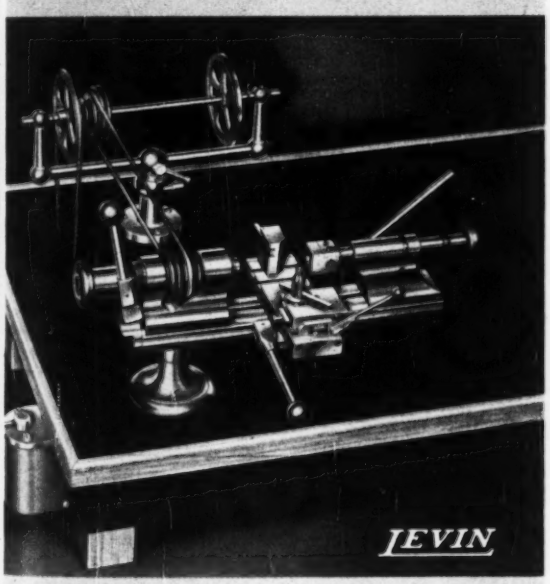
Send for catalog describing Stroke and Revolution Counters, Coil Winding Counters, Panel-mounted Electric Counters, Automatic Electric Batch Counters and Counter Actuating Switches.

Great dependability, small space requirement, tamperproof construction and Low Cost. The ideal combination in Mechanical and Electric Counters for built-in applications.

Speeds to 600 CPM. Non-reset. SMC Stroke Counters furnished with any required shaft extension and operating arm. MERCURY Electric Counters furnished for any required voltages, either AC or DC. Send application details for sample.

Production Instrument Company
702 W. JACKSON BLVD., CHICAGO 6, ILL.
Representatives in Principal Cities

PRECISION LATHES FOR SMALL WORK



Ideal for second operations on instrument parts or other small pieces. 4" swing—collet capacity 5/16" or 3/16". Send for Bulletin "F" containing a complete description of lathes and accessories.

LOUIS LEVIN & SON, INC. • 782 EAST PICO BLVD. • LOS ANGELES 21

New Portable Field Manometer by MERIAM

For Checking Calibration of Gas Orifice Meters in the Field...

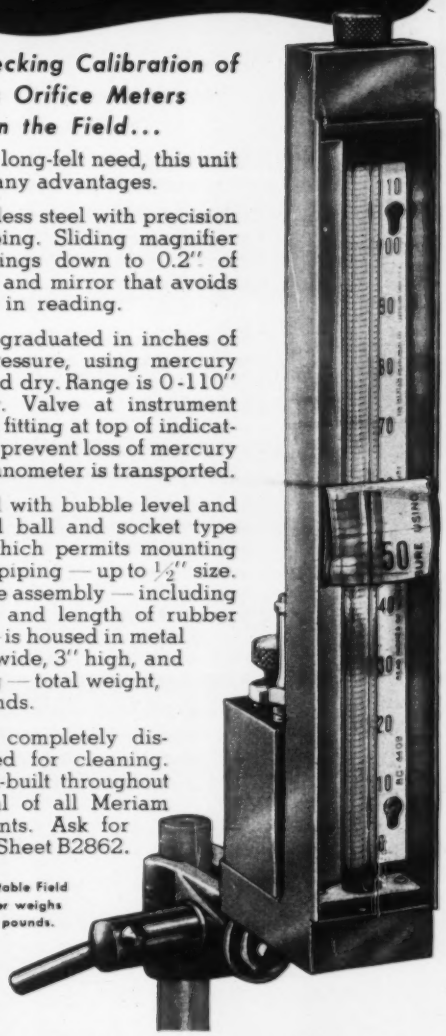
Filling a long-felt need, this unit offers many advantages.

All stainless steel with precision bore tubing. Sliding magnifier for readings down to 0.2" of water — and mirror that avoids parallax in reading.

Scale is graduated in inches of water pressure, using mercury calibrated dry. Range is 0-110" of water. Valve at instrument well and fitting at top of indicating tube prevent loss of mercury when manometer is transported.

Provided with bubble level and universal ball and socket type clamp which permits mounting to meter piping — up to ½" size. Complete assembly — including mercury and length of rubber tubing — is housed in metal case 5" wide, 3" high, and 14" long — total weight, 7½ pounds.

Can be completely disassembled for cleaning. Precision-built throughout — typical of all Meriam instruments. Ask for Catalog Sheet B2862.



Handy Portable Field Manometer weighs only 3¾ pounds.

THE MERIAM INSTRUMENT CO.
10958 MADISON AVENUE • CLEVELAND 2, OHIO
WESTERN DIVISION: 4760 E. OLYMPIC BLVD., LOS ANGELES 22, CALIF.
IN CANADA: PEACOCK BROS., LTD., MONTREAL

MERIAM Instruments
ESTABLISHED 1911

MANOMETERS, METERS AND GAUGES FOR THE ACCURATE MEASUREMENT OF PRESSURES, VACUUMS AND FLOWS OF LIQUIDS AND GASES

No. 35—Product of
Jas. P. Marsh Corp., Skokie, Illinois

Chace Thermostatic Bimetal tells the "inside story" at a glance, in this easy-to-read home indoor-outdoor thermometer. A small bimetal coil is fixed at one end to the indicator shaft, with the other end attached to the back of the dial. Changes in temperature cause rotation of the bimetal coil, moving the indoor indicating pointer to the correct temperature value.

Chace #6650 Thermostatic Bimetal is specified, being particularly suitable for temperature indicators from −100° F. to +500°F., due to its extremely high deflection rate.

Manufacturers in many fields are taking advantage of the wide range of properties found in the complete line of Chace Thermostatic Bimetals. They've gained new freedom of design and improved product performance in such varied industries as automotive, appliances, instruments and industrial equipment. As the actuating element for *your* product in the field of temperature indication or control . . . specify Chace Thermostatic Bimetal.

W. M. CHACE CO.
Thermostatic Bimetal
1609 BEARD AVE., DETROIT 9, MICH.

must be simple in construction and unaffected by chemical action of the reagent.

The method illustrated in Fig. 84-C has been used satisfactorily on applications similar to pH and should present no serious difficulty in pH control. It consists of a pressure-loaded regulator connected across the control valve through seal pots containing an immiscible oil which also fills the regulator head. It regulates pump by-pass to maintain required pressure across the control valve.

An air purge system (Fig. 84-D) was recently applied successfully by the writer to a process in which the reagent was a heavy syrupy material. Air purge across the valve is controlled by two constant-differential pressure regulators which maintain constant pressure-drop across a fixed orifice, thus establishing fixed purge into the reagent line. Pressure differences between the two regulators is measured and recorded by a recording pressure-difference controller which operates a by-pass around the reagent supply pump to maintain fixed drop across the control valve.

Other reagent feed systems have been used and still others may be designed to operate in a specific manner to accomplish desired end results. Cost analysis and performance limitations are the guiding factors which determine the best method for a given job.

It is a customary procedure in water treatment and waste disposal practice to feed reagent into a long trough having one saw-toothed edge for equalized distribution of reagent across a Parshall flume or open channel; or sometimes the reagent valve may feed directly into a large weir box, which, in turn, gages reagent flow and spills it into the treating channel.

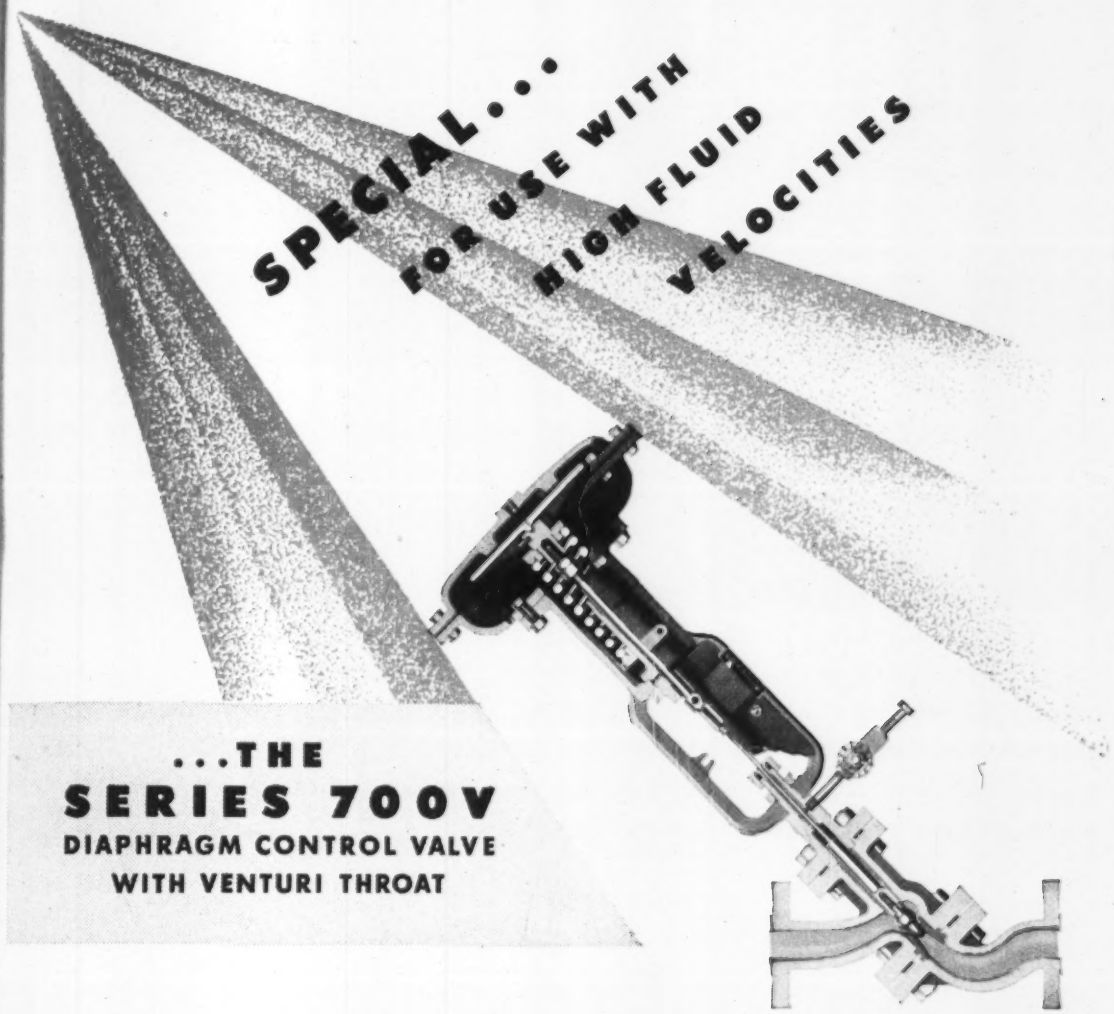
If reagent flow must be gaged, it should be done another way and the weir box eliminated entirely since it delays reagent transfer by virture of its supply-side capacity lag. This condition applies in general to all distributors and transfer devices which may be connected to the discharge side of the reagent control valve. Their volume hold-up should be minimal, and line sizes should be *as small as possible*, to permit high velocity transfer of reagent to the process. Saw-toothed distribution boxes should not be of excessive width, since the added volume requires reagent and time to fill it and delays transfer to the process. If the distributor is long and spans a wide flume, it should be fed uniformly through a branched discharge header from the valve, and the header should be sized appropriately for maximum transfer velocity.

The same condition applies to "T" head distributors sometimes used in open-trough applications of industrial plants. It is not uncommon practice to terminate the valve discharge line into a submerged "T" distributor for control in open troughs, the downstream side being drilled with a multiplicity of holes to "fan" reagent into the flowing stream. Ordinarily, one may find the concept good but applied practice poor. An inspection of such distributors that have been in service usually reveals a "T" branch of larger size pipe than the feed line and, not uncommonly, the end holes plugged entirely or otherwise inactive, and the center section taking all reagent feed.

The important feature of design of "T" distributors is their velocity-distance component. Each branch should be sized by reference to Fig. 45 to give a velocity-distance component equal to twice the nominal velocity-distance component of the feed header which, conversely, should equal one-half the sum of both branches. For example, if the feed header transfers one gallon of reagent a distance of one foot in one second, each branch of the "T" distributor should be appropriately sized to transfer this same gallon of reagent a distance of two feet in one second. Sizing of the discharge holes is also important and should follow a pattern of increasing diameter toward the ends of the branch to provide decreasing pressure drop.

* * *

The technique of controlling pressure drop across the control valve has been widely applied to industrial control and offers advantages in pH regulation. For example a pH regulator may be cascaded with a liquid level or flow regulator as indicated in Fig. 85 in such a manner as to control pressure drop across the main control valve VA-1 by manipulating valve VA-2. The principal advantage of



. . . THE SERIES 700V DIAPHRAGM CONTROL VALVE WITH VENTURI THROAT

HIGH fluid velocities . . . even viscous fluids and fluids containing suspensions . . . are pushovers for the Series 700V. A special venturi throat eliminates the sudden change in direction of flow so often the cause of trouble under such conditions. As a result, in-service time is unusually high.

OUTSTANDING FEATURES OF THE 700V

- *Special flushing connection to keep stem operation free.*
- *Special materials for body and trim to meet prevailing operating conditions.*
- *Special design, renewable disc and seat ring.*
- *Special provision for field conversion from straight through to angle operation.*

You'll save a lot in maintenance costs alone, if you standardize on the Series 700V for high fluid velocities. Call in your local Honeywell engineer for complete information . . . he is as near as your phone!

COMMERCIAL · RESIDENTIAL · INDUSTRIAL
WORLD'S LARGEST ORGANIZATION FOR ADVANCED INSTRUMENTATION AND CONTROL

MINNEAPOLIS-HONEYWELL REGULATOR CO.
BELFIELD VALVE DIVISION
Philadelphia 44, Pa.
Offices in 73 principal cities of the United States, Canada and throughout the world

MINNEAPOLIS Honeywell — *Diaphragm Valves* AND PROCESS CONTROL SPECIALTIES — Belfield DIVISION

THE LIQUIDOMETER CORP.
36-27 SKILLMAN AVE., LONG ISLAND CITY, L.N.Y.

The Golay

INFRA-RED DETECTOR

Is a superior detector for use in infra-red spectroscopy. It has been acclaimed as presenting the best all around characteristics of sensitivity, speed, reliability and spectral uniformity of response.

These detectors can be manufactured to fit most of the infra-red spectrometers in use today, and we solicit inquiries regarding such applications.

The Golay Infra-Red Detector is manufactured by The Eppley Laboratory, Inc., under the personal supervision of Dr. Marcel J. E. Golay.

Write for Bulletin No. 10c.

EPLAB

THE EPPLEY LABORATORY, INC.

Scientific Instruments

NEWPORT • RHODE ISLAND • U. S. A.

this system is its inherent fail-safe characteristics but, like any other cascaded system, it must be appraised for its specific application.

Another novel application of the pressure-drop technique is illustrated in Fig. 86. A common influent stream is divided between two batteries of converters, one battery of which generates an alkaline material while output

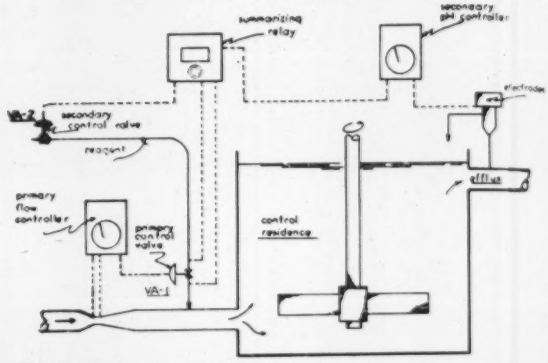


Fig. 85. Series valve cascaded pH control process incorporating primary reagent feed as a function of process liquor flow and secondary correction as a function of pH.

of the other battery is acidic. Effluents from these converters must be regulated in volume throughput to meet demands of subesequent process units, and must also be ratioed to adjust final pH.

Valves VA-1 and VA-2 adjust pH while VA-3 and VA-4 regulate throughput. The pH of the combined effluent streams is measured by recorder-controller pHC-1, which actuates simultaneously direct-acting valve VA-1 and reverse-acting valve VA-2. Level in the accumulator is a

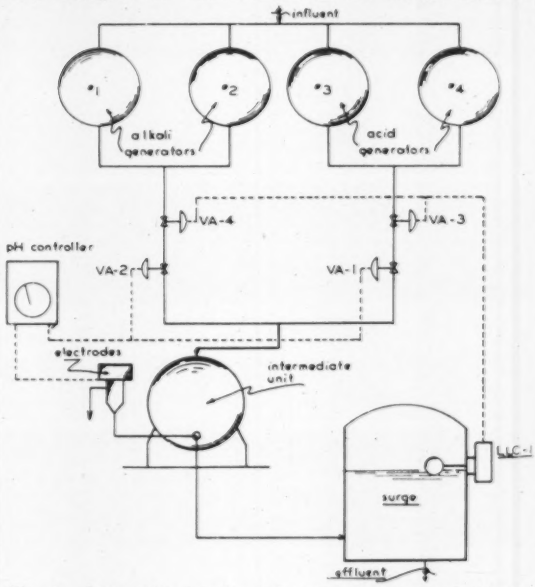


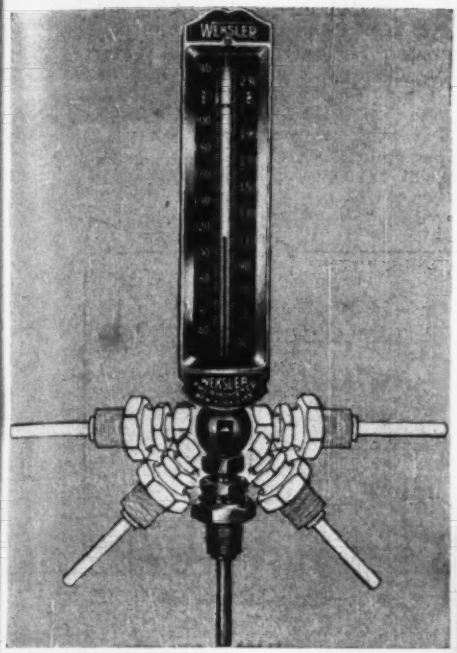
Fig. 86. Series valve cascaded pH control process incorporating combined throughput control and pH regulation. Unit regulators of this process are interdependent.

measure of throughput and LLC-1 becomes the flow regulator which actuates opposed-acting valves VA-3 and VA-4.

Although this process has unique features, it is basically unstable and requires external stabilization such as the intermediate capacity and accumulator to avoid individual regulators "fighting" one another. Should either battery of converters become clogged or "spent," either the flow regulator or pH regulator, or both will act to alleviate the condition. However, there is nothing to prevent under-

WEKSLER
— N.Y.C. —

Swings A New Angle on Thermometer Installation



180° SWING • FRONT TO BACK • LEFT TO RIGHT

sensational

- **ADJUST-ANGLE** simplifies maintenance—reduces stock requirements.
- **ADJUST-ANGLE** is visible at any angle—simple installation.
- **ADJUST-ANGLE** minimizes breakage—easily adjusted.
- **ADJUST-ANGLE** is supplied with INTERCHANGEABLE Union or Separable socket.
- 7, 9 or 12-inch cases—3½ to 30" stem.

Your design staff, purchasing department or maintenance engineers should have our Adjust-Angle Thermometer Bulletin AA-4 — Write for it.

WEKSLER also makes all types of Glass Thermometers, Hydrometers, Psychrometers, Hygrometers, Pressure Gauges and Dial Thermometers, Pressure and Temperature Recorders.

For quotations, send complete specifications.

INSTRUMENTS FOR INDUSTRY

WEKSLER THERMOMETER CORP.

52-56 West Houston Street NEW YORK 12, N. Y.

ADJUST-ANGLE

FOR BETTER

pH Control and WATER TESTS

there is nothing like

NON-FADING GLASS COLOR STANDARDS

Pocket Comparator No. 605

Permanent reliability of Hellige Glass Color Standards, accuracy of color comparison, simplicity of technique, and compactness of the apparatus are exclusive features of Hellige Comparators.

WRITE FOR BULLETIN No. 602

HELLIGE

INCORPORATED

3718 NORTHERN BLVD. LONG ISLAND CITY 1, N.Y.

HEADQUARTERS FOR COLORIMETRIC APPARATUS

RELAYS *and* TIME SWITCHES

of Diamond AEMCO *Quality*

Open Type
"Can" Type
With Plug-in Tube Base
A. C. or D. C. Midget Relays
Dual Purpose Relays
Delayed "Make" or "Break"
Automatic Circuit Control
"Current" and "Potential" Relays

Ruggedly constructed to exacting specifications that are carefully engineered to provide ample safety factor . . . quality all the way through!

Automatic's relays are not built to a price but to an unexcelled standard of performance. That's why they are the choice of so many "big name" manufacturers.

We engineer and build a wide variety of stock model relays for practically all applications. A staff of competent engineers will design and build relays to fit *your* requirements.

Stock models or custom built, every relay we manufacture will deliver the same dependable performance that has made the "Diamond Seal" line the choice of those who measure *quality* by *performance*.

- **TIME SWITCHES — Equipped with Synchronous Self-Starting Motors and Silver Contacts.**

For any load, for every installation, look to Automatic for the finest in Time Switches and Interval Timers.

WRITE FOR CATALOG

AEMCO

Automatic Electric MFG. CO.

58 STATE STREET · MANKATO, MINN.

"Veeder-Readings"
ARE DIRECT READINGS

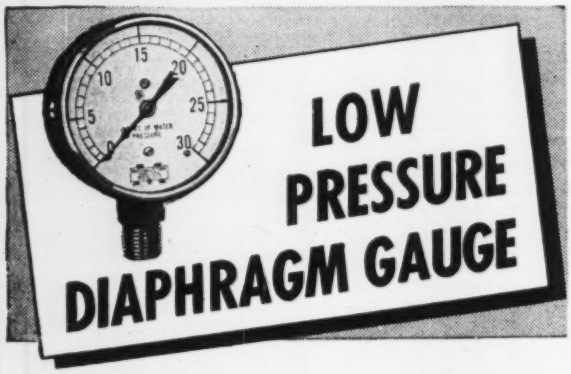
...THAT MINIMIZE CONVERSIONS, ERRORS, DELAYS

Put an end to the setting and reading of hairline-graduated dials on all types of machines.

Install a Veeder-Root Counting Device that will give direct and accurate Control over rate of feed, depth of cut, or any other phase of operation.

Then operators and inspectors get their Facts-in-Figures directly, plainly, *unmistakably* . . . in bold, easy-to-read figures that don't have to be converted, decoded or otherwise translated.

The Counting House of Industry
VEEDER-ROOT INC.
Hartford 2, Connecticut
In Canada: Veeder-Root of Canada, Ltd., 955 St. James St., Montreal 3. *In England:* Veeder-Root Ltd., Dickinson Works, 20 Purley Way, Croydon, Surrey.



MARSHALLTOWN Figure 83 is a very sensitive instrument utilizing a diaphragm for pressure communication, and is recommended for extremely low pressure service.

The following standard dials reading in inches of water are available—0-15" 0-30" 0-60" 0-100" 0-150".

Ounce graduated dials can also be supplied in a range from 16 ounces to five pounds.

It is available in the 2½", 3½", and 4½" dial sizes and mounted in a black enameled, deep steel case. Write for details and price.

MARSHALLTOWN manufactures one of the most complete lines of indicating pressure gauges—there is a Marshalltown gauge for every purpose and pressure.

Marshalltown Mfg. Co., Marshalltown, Iowa

correction in the event of "spent" converters, except full closure of one valve and opening of the other. When this condition occurs, a closing contact sounds an alarm.

* * *

Needless to say that composition of reagent must be uniform for all applications to eliminate unnecessary loads on the regulator. If the reagent is a slurry of solid material suspended in a liquid vehicle, it is necessary to circulate it in a closed loop at sufficient velocity to prevent settling as described in the foregoing text. Butterfly valves have been used satisfactorily as vertical take-off controls on slurries of lime up to 16 percent (Fig. 87). Vertical up-take through the butterfly valve minimizes plugging of the wing at partial open positions.

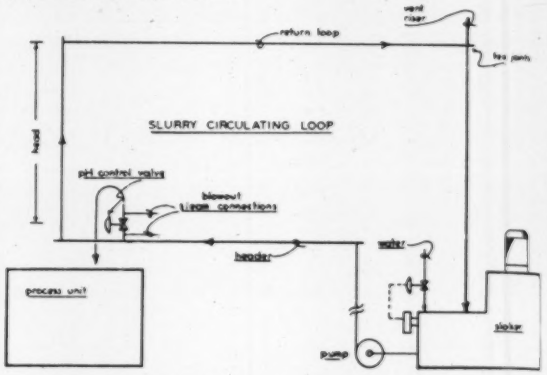


Fig. 87. Reagent slurries must be circulated constantly and agitated thoroughly to maintain uniform concentration and avoid plugging.

It has been found good practice to use flanged tees at all pipe turns and install steam purge lines on both sides of the valve to facilitate removal of cake or plugs which may accumulate during shut-down. Furthermore, the supply header and return loop should slope toward the supply source to permit self-drainage of the line in event of pump stoppage. Head on the valve is established by a vertical riser in the loop. Siphoning action of the return leg is broken by means of a vent riser at the point of down-take.

In many cases it is customary practice to feed dry chemical reagent to a process with a mechanical feeder. When such equipments are used as part of the pH control loop wherein a pH regulator adjusts feed rate directly, it is desirable to avoid as much transfer lag and supply-side storage lag as possible. In general it will not be convenient to reduce these lags to values comparable with liquid feed installations; therefore all precautions should be taken to make reagent transfer to the process as direct as possible, but with due regard for *equilibrium lag* which may result if sufficient time is not allowed for dissolving and occlusion reactions to reach equilibrium.

To be continued

FINAL REMINDER

Dead-line for the $500 Instrumentation Essay Contest is Tuesday, January 31st.

Entries must be mailed early enough to be received not later than that date at the office of the sponsor, The Instruments Publishing Company.

Address entries to Contest Editor, 921 Ridge Avenue, Pittsburgh 12, Pa.

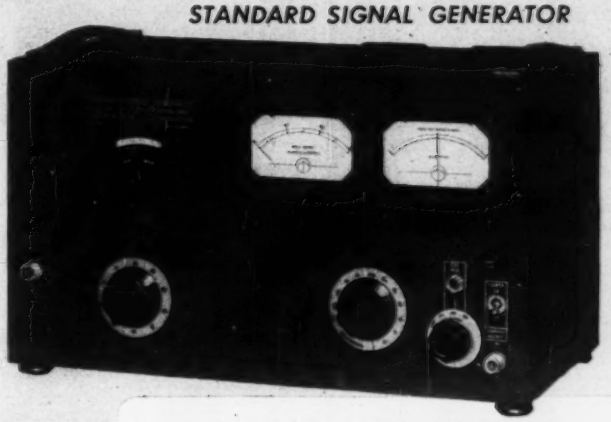
For rules, see page 934 of October issue; or page 1009 of November issue; or page 1124 of December issue.

Positive Contact Plugs and Jacks permit 80 thermocouples, regardless of location, to be selected and switched to any of 80 Pyrometer recording points. *When your Thermocouple Circuits require flexibility of connections or arm-length control, let us help you.*

Send for Panel Bulletin 21F

Thermo ELECTRIC CO.
FAIR LAWN. N.J.

MEASUREMENTS CORPORATION *MODEL 80*
STANDARD SIGNAL GENERATOR



2 to 400 MEGACYCLES

MODULATION: Amplitude modulation is continuously variable from 0 to 30%, indicated by a meter on the panel. An internal 400 or 1000 cycle audio oscillator is provided. Modulation may also be applied from an external source. Pulse modulation may be applied to the oscillator from an external source through a special connector. Pulses of 1 microsecond can be obtained at higher carrier frequencies.

FREQUENCY ACCURACY ±.5%

OUTPUT VOLTAGE 0.1 to 100,000 microvolts

OUTPUT IMPEDANCE 50 ohms

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Phase Sequence Indicators
Television and FM Test Equipment

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

N
F/C PNEUMATIC TRANSMITTER
W

IDEAL FOR MEASUREMENT OF—LEVEL—FLOW PRESSURE—SPECIFIC GRAVITY—DIFFERENTIAL PRESSURE

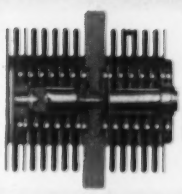
AVAILABLE MATERIALS
STEEL
BRONZE
STAINLESS
HAVEG
HASTELLOY
MONEL

Non-overloading type diaphragm—Extreme accuracy. Available for high and low pressures.

Write for Bulletin

TULSA **INSTRUMENTS, INC.** OKLA.

RUPTURE-PROOF
BELLOWS TYPE
FLOW METERS
EXCLUSIVELY BY
BARTON



FLOW • LIQUID LEVEL
DIFFERENTIAL PRESSURE
ONLY BARTON OFFERS

★ POSITIVE OVER-RANGE PROTECTION
Rupture-Proof Bellows Unit Permits Over-Range to Rating of Housings Without Damage

★ VITAL PARTS PROTECTED
Torque-Tube, Bearings and Pivots Sealed in Lubricating Liquid • No Corrosion by Line Fluids

★ SELF DRAINING AND VENTING
Line Fluid Contacts Outside of Each Bellows • Condensate or Surges of Liquid Drain from Housings

Send For Complete Information
Representatives in Principal Cities

BARTON INSTRUMENT COMPANY
1431 S. Eastern Ave.
Los Angeles 22
California

CLEAN
BEARINGS
CONTACT POINTS

Call or write for information on the **ENG-SOL METHOD** of chemically cleaning surfaces with a high velocity spray of solvent and air.

•

PASSAIC ANALYTICAL LABORATORIES, Inc.
228 AYCRIGG AVE. PASSAIC, N. J.

ONLY the new electronic
Moisture Register
MODEL DC-2
gives you all these features for $89.50

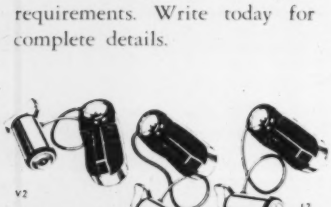
• Dual range, tests from 6% to 28%. • Micro-ammeter adjustment for extreme accuracy. • Direct reading, instant calibration, simple to operate. • Complete shielding from outside electrical interference. • Temperature correction from 40 to 240 degrees F. • Automatic compensation for voltage and tube variation. Operates on resistance principle. • One-year guarantee.

Equipped with long-life, low cost batteries. Weighs 5 lbs., self-contained in walnut case ruggedly constructed. Dimensions 10"x6"x4".

PLUS 10 DAY
FREE TRIAL

Try the new Model DC-2 for 10 days free. No obligation. Send for it today. Use it, test it and prove its superiority.

DC-2 is one of 4 instruments specifically designed for testing moisture in wood and wood products. Instruments are also manufactured especially for the textile, paper and leather trades. There is a model to fit your requirements. Write today for complete details.



The standard in moisture testing

ELECTRONIC MOISTURE REGISTER
133 North Garfield Avenue
Alhambra, California

Manufacturers New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 99.

S-1 LABORATORY APPARATUS. Two bulletins, "Laboratory Spotlight No. 4" and "Laboratory Spotlight No. 5" illustrate and describe maker's laboratory instruments and apparatus. No. 4 covers spectrophotometer, precision balance, x-ray diffraction unit, washers, stirrers, etc.; No. 5 covers "Polaro-analyzer," torsion balance, thermometers, hot plates, etc.; No. 5 contains 1947 revised atomic weight table.—Harshaw Scientific Div., Harshaw Chemical Co., Cleveland 6, Ohio.

S-2 FLOW CONTROL VALVE. 4-page Bulletin WH-100 illustrates and describes maker's flanged silent check valve; lists exclusive features; shows typical applications.—The Williams Gauge Co., 1620-22-24 Pennsylvania Ave., Pittsburgh 12, Pa.

S-3 "GENERAL RADIO EXPERIMENTER." 8-page Vol. XXIV, No. 6 issue of this house organ features articles on maker's "Type 1022-A" F-M standard-signal generator, and "Type 1023-A" amplitude modulator—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

S-4 DRAFTING TEMPLATES. 2-page circular illustrates use of maker's "Flowplanner" template for flow plan drawing; contains sample drawings, full-size illustrations of templates. —Timely Products Co., Box 206-B, Columbus 9, Ohio.

S-5 VACUUM COATING UNITS. 16-page bulletin illustrates and describes maker's units for coating metal and other objects in high vacuum; discusses process and various units; lists advantages, characteristics.—Distillation Products, Inc., Rochester 13, N. Y.

S-6 AIR-OPERATED CONTROLLERS. 32-page Bulletin No. A120 illustrates and describes maker's new line of "Series 500" air-operated controllers; lists features, complete data on on-off, proportional, reset, derivative, reset plus derivative models.—The Bristol Co., Waterbury 20, Conn.

S-7 STEAM, AIR, OIL, ETC. STRAINERS. 4-page Bulletin S-202 describes and illustrates maker's fine screen strainers for hot or cold services in steam, water, air, oil and gas lines; lists types, sizes; discusses uses—Yarnall-Waring Co., Chestnut Hill, Philadelphia 18, Pa.

S-8 FLUE GAS ANALYZER. 4-page Bulletin No. 1136B illustrates and describes maker's continuous indicating and recording flue gas analyzer; discusses theory of operation, construction features; lists available units, accessories.—Instruments Div., Davis Emergency Equipment Co., Inc., 47 Halleck St., Newark 4, N. J.

S-9 AUTOGRAPHIC TITROMETER. 12-page Bulletin 640A describes and illustrates maker's "Recordomatic" titrometer for automatic control of reagent feeding; discusses advantages, operation, range; contains "Question and Answer" page; gives ordering data.—Precision Scientific Co., 3737 W. Cortland St., Chicago 47, Ill.

S-10 ILLUMINATED LAYOUT PLATE WITH MICROSCOPE. 2-page bulletin describes and illustrates maker's illuminated layout plate with microscope for surface inspection; lists features, specifications.—All American Tool & Mfg. Co., 1014 Fullerton Ave., Chicago 14, Ill.

S-11 MICROPHOTOMETER. 4-page bulletin describes and pictures maker's "Romicron" microphotometer; lists special features; discusses calibration procedure.—Paul Rosenthal, 505 Fifth Ave., New York 17, N. Y.

S-12 RADIATION COUNTER. 4-page bulletin illustrates and describes maker's model "RM 1" portable, battery-operated radiation counter; discusses typical applications; specifications.—The Nucleonic Corp. of America, 497 Union St., Brooklyn 31, N. Y.

S-13 FLOW-RATE INDICATOR. 2-page bulletin describes and pictures maker's "Fluguide" gas flow-rate indicator; lists features; gives capacity and dimension tables.—Fisher & Porter Co., Hatboro, Pa.

S-14 TIMING DEVICES. 6-page bulletin describes and illustrates maker's timing devices, switches, etc.; lists applications, features, data on each.—M. H. Rhodes, Inc., 30 Bartholomew Ave., Hartford 6, Conn.

S-15 "hp JOURNAL." 4-page Vol. 1, No. 3 issue of this house organ features part one of a two-part article titled "Design Notes on the Resistance-Capacity Oscillator Circuit."—Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

S-16 "CEC RECORDINGS." 10-page Vol. 3, No. 4 issue of this house organ features article titled "Magnetic Susceptibilities of Heavy Metal Compounds"; also articles on maker's "Titrilog," oscillograph record magazine, mass spectrometer.—Consolidated Engineering Corp., 620 N. Lake Ave., Pasadena 4, Calif.

S-17 "INSTRUMENT NEWS." 8-page Vol. 1, No. 1 issue of this house organ features an article titled "Use of Infrared Expands in Drug, Biochemical Fields"; contains section "Tricks of the Trade" on use of electro-optical instruments.—The Perkin-Elmer Corp., Glenbrook, Conn.

S-18 ELECTRONIC CONTROL. 64-page book, "Cutting Production Costs with Electronic Controls," illustrates and discusses 45 case studies on industrial control problems solved through use of electronics.—Photoswitch, Inc., 77 Broadway, Cambridge 42, Mass.

S-19 LABORATORY ROD CLAMPS. 2-page bulletin illustrates and describes maker's rod clamps for semi-permanent setups in the laboratory; lists features, types, dimensions.—Chandler & Stedman, 398 Newton St., Waltham 54, Mass.

S-20 "SCIENTIFIC APPARATUS AND METHODS." 38-page fall 1949 edition of this house organ features article titled "The Polarography of Carbonyl Compounds"; Section two lists new, reinstated, discontinued items, specification changes; encloses "Table of Half-Wave Potentials."—E. H. Sargent & Co., 4647 W. Foster Ave., Chicago 30, Ill.

S-21 COMBUSTION CONTROLLERS. 12-page Bulletin SC-2.1 describes and illustrates maker's combustion controllers; discusses uses, operation, design and construction, capacities and pressures, selection procedure; gives typical applications; lists features.—Selas Corp. of America, Philadelphia 34, Pa.

S-22 STANDARD MEASURING MACHINE. 8-page Circular No. 523 illustrates and describes maker's standard measuring machine; discusses operation, features, accessories; lists specifications.—Pratt & Whitney, West Hartford 1, Conn.

S-23 STRAIN GAGES. 12-page Bulletin No. 279-A describes and illustrates use of maker's "SR-4" bonded resistance wire strain gages in stress analysis; illustrates eight circuits with accompanying instruments.—Baldwin Locomotive Works, Philadelphia 42, Pa.

S-24 MEGOHMMETER. 4-page Bulletin No. 1029 illustrates and describes maker's "Model 29" megohmmeter for resistance measurement over a range from 300,000 ohms to 20,000,000

mechanisms; discusses principle of operation, accuracy; lists specifications.—Herman H. Sticht Co., Inc., 27 Park Place, New York, N. Y.

S-25 GAS AND LIQUID ANALYZER. 4-page Bulletin No. DZ-4 describes and illustrates maker's "Lira" infrared gas and liquid analyzer; discusses operation, applications.—Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh 8, Pa.

S-26 "THE LABORATORY." 48-page Vol. 19, No. 2 issue of this house organ features article titled "Taste Takes a Trip to the Laboratory"; containes articles on maker's electroviscometer, temperature and pressure recorders, etc.—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

S-27 A-C REGULATORS. 12-page Catalog No. A-1049 illustrates and describes maker's a-c electronic voltage regulators; contains performance chart; lists electrical and mechanical specifications, and unusual voltage conditions of each model.—Sorensen & Co., Inc., 375 Fairfield Ave., Stamford, Conn.

S-28 D-C POWER SOURCES AND SUPPLYS. 8-page Catalog No. B-1049 describes and illustrates maker's "Nobatron" d-c. power sources and power supplys; lists electrical and mechanical specifications.—Sorensen & Co., Inc., 375 Fairfield Ave., Stamford, Conn.

S-29 CARBIDE GAGES. 8-page bulletin lists ranges, accuracies, prices of maker's go, not go, and progressive standard plug and ring gages with carbide inserts.—Arthur A. Crafts Co., Inc., 603 Newbury St., Boston 15, Mass.

S-30 MACHINE SHOP GAGES AND TOOLS. 8-page bulletin illustrates and describes maker's diamond and carbide tools, wear parts, gages, diamond dust; lists prices.—Arthur A. Crafts Co., Inc., 603 Newbury St., Boston 15, Mass.

S-31 "S-L INSTRUMENT NOTES." 4-page No. 12 issue of this house organ features article titled "The Meaning of 'Natural Frequency' "; also contains index of articles published in preceding issues.—Statham Laboratories, 9328 Santa Monica Blvd., Beverly Hills, Calif.

S-32 CONTROL VALVES. 2-page folder describes and illustrates maker's control valves for industrial use; lists sizes, uses of temperature regulators, feed regulators, etc.—Atlas Valve Co., 280-284 South St., Newark 5, N. J.

S-33 "SK ENGINEERING NEWS." 4-page Vol. 1, No. 3 issue of this house organ contains article titled "Rotameters Can Provide Close Control Over Batch Process"; also features items on maker's rotameters, condensers, fume scrubbers, oil heaters.—Schutte & Koerting Co., 1185 Thompson St., Philadelphia 22, Pa.

S-34 PRECISION ANEMOMETER. 2-page bulletin illustrates and describes maker's "Precision Air-Meter" for measuring low air or gas velocities; lists characteristics, advantages; discusses principle of operation.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

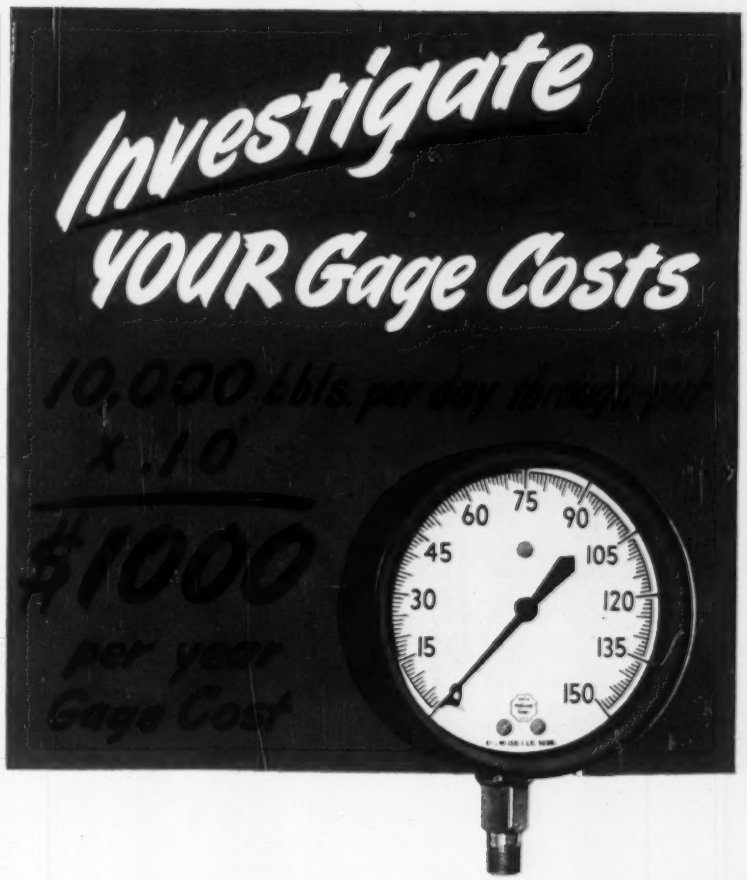
S-35 SHIP POSITION PLOTTING. 4-page reprint from The Oil and Gas Journal, July 7, 1949, of article titled "A Method of Surveying by Use of Radio Waves" and 2-page bulletin, "Raydist Automatically Records A Vessel's Exact Position and Course," discuss history, development and operation of maker's "Radist" ship position and course plotting system.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

S-36 ELECTRONIC STANDARD CELL. 2-page bulletin describes and illustrates maker's electronic standard cell; lists features, characteristics.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

S-37 PORTABLE ANEMOMETER. 2-page bulletin illustrates and describes maker's "Air-Meter" portable anemometer; lists features, characteristics; discusses principle of operation; lists accessories.—Hastings Instrument Co., Inc., P. O. Box 1275, Hampton, Va.

S-38 "THE OHMITE NEWS." 2-page November issue of this house organ features article titled "More Uniform Control Achieved with Taper-wound Rheostats"; also contains articles on maker's resistors.—Ohmite Manufacturing Co., 1835-41 Flournoy St., Chicago 44, Ill.

S-39 COLOR MEASUREMENT. 4-page bulletin illustrates and describes maker's "Color-

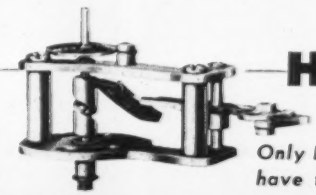


●Your replacement cost of pressure gages may be higher than you think. For example, in an oil refinery the average annual cost runs about 10¢ per barrel daily through-put. On that basis, a small 10,000 barrel refinery spends about $1000 a year for new gages. And the cost of parts, repairs and maintenance is much higher.

Investigate your own gage costs! They may be much more than they should be.

Helicoid gages last longer—many times longer than conventional gages—at about the same price.

Specify HELICOID to cut your gage costs.



HELICOID

Only Helicoid Pressure Gages have the Helicoid Movement.

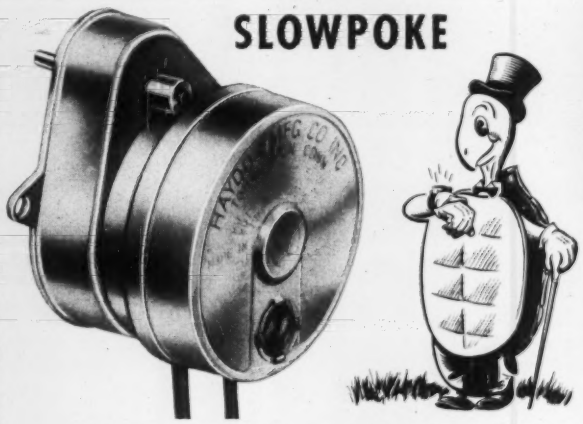
ACCO

TRADE MARK

HELICOID GAGE DIVISION
AMERICAN CHAIN & CABLE COMPANY, INC.
Bridgeport 2, Connecticut

Timing Ideas

HERE'S A COMPACT SLOWPOKE



Designers and manufacturers concerned with the excessive space requirements and high cost of external reduction gearing will welcome this new slow speed timing motor. The series 4400 requires minimum space and provides, at comparatively low costs, speeds from 6 hours to 7 days per revolution. The careful design, expert engineering and precision manufacture, are advantages common to all Haydon motors.

SUPERIORITY FEATURES

DEPENDABILITY: Slow 450 rpm rotor speed means less reduction gearing and fewer fast wheels, providing quieter operation and longer life.

SMALL SIZE: Smallest available of this type.

TOTAL ENCLOSURE: A basic feature of sound design.

CONTROLLED LUBRICATION: Separate rotor and reduction gearing lubricating systems permit selection of best methods and lubricants, control circulation, insure against leakage.

OPERATING POSITION: Operates continuously in any position.

SIMPLE, SECURE ASSEMBLY: Entire face of motor can be supported securely against mounting surface. Motor leads standard for quick, inexpensive wiring.

STANDARD INTERCHANGEABLE DESIGNS: Speed from 300 rpm to 1 revolution per week in only 2 interchangeable motor series.

For complete design and engineering specifications, write for catalog: Timing Motors No. 322 — Timers No. 323 — Clock Movements No. 324. Yours without obligation.

HAYDON AT TORRINGTON

HEADQUARTERS FOR TIMING

HAYDON Manufacturing Co., Inc.

2025 ELM STREET

TORRINGTON, CONNECTICUT

SUBSIDIARY OF GENERAL TIME CORPORATION

Eye," a new industrial color measuring and comparison instrument designed to replace the human observer in precise color-matching problems; lists features and technical specifications.—Instrument Development Laboratories, Inc., 163 Highland Ave., Needham Heights 94, Mass.

S-40 THICKNESS MEASUREMENT. 8-page bulletin describes and illustrates maker's "IDL Opti-Mike" thickness microscope which permits, for the first time, precise thickness measurement of glass, plastics, quartz, and any other transparent material where physical access to one side only is possible; lists performance characteristics, typical applications.—Instrument Development Labs., Inc., 163 Highland Ave., Needham Heights 94, Mass.

S-41 WASTE CONTROL. 16-page booklet, "Solving Industrial Crimes—Case No. 38," describes solution to one company's excess lighting load problem; lists applications of maker's recording instruments in various industries to help eliminate waste.—The Esterline-Angus Co., Inc., Indianapolis 6, Ind.

S-42 ELECTRICAL INSTRUMENTS. 4-page Bulletin C-50 illustrates and describes maker's switchboard instruments; lists specifications, types available; encloses 8-page price list.—Reliance Instrument Co., 3027 W. Van Buren St., Chicago 12, Ill.

S-43 MACHINABILITY TESTER. 8-page bulletin illustrates and describes maker's "MSE Schlesinger" machinability tester for measuring machinability in establishing machinability standards; discusses operation, application; explains "machinability index" and tool standardization.—Vanton Equipment Corp., Empire State Bldg., New York 1, N. Y.

S-44 TIMING MOTORS. 4-page bulletin describes and illustrates maker's "SC" and "LC" timing motors; lists special features, specifications, dimensions, speeds.—International Register Co., 2616 W. Washington Blvd., Chicago 12, Ill.

S-45 VARIABLE-AREA RECORDER AND REPRODUCER. 4-page bulletin illustrates and describes maker's variable-area recording and reproducing instruments for analysis of seismic impulses under laboratory conditions; lists specifications; describes power supply.—Seismograph Service Corp., Tulsa, Okla.

S-46 VIBRATION TEST MACHINES. 4-page bulletin describes and illustrates maker's "Type RVCG" constant G, and "Type RVCA" constant-amplitude vibration test machines; lists features, dimensions, specifications.—L.A.B. Corp., 31 Union Pl., Summit, N. J.

S-47 SHUTOFF VALVE. 2-page Bulletin No. 21S illustrates and describes maker's "21 Series" safety shut-off valve; lists features, applications.—The North American Mfg. Co., Cleveland 5, Ohio.

S-48 SIGNAL CALIBRATOR. 2-page bulletin describes and illustrates maker's "Electro-Cal" signal calibrator for laboratory measurements; lists special features, range, output specifications.—Industrial Electronics, Inc., 2457 Woodward Ave., Detroit 1, Mich.

S-49 INDUSTRIAL ANALYZER. 2-page bulletin describes and illustrates maker's "Model 247" portable electrical industrial analyzer; discusses operation, application; lists specifications.—Instrument Laboratories, 315 W. Walton Pl., Chicago 10, Ill.

S-50 "MODERN PRECISION." 8-page Vol. 9, No. 3 issue of this house organ features articles on maker's electrodes for industrial pH measurement, integrated control for furnaces, "Micromax" controllers and recorders in metals, process industries, ceramics, power, research, teaching and testing.—Leeds & Northrup Co., 4902 Stenton Ave., Philadelphia 44, Pa.

S-51 INDUSTRIAL MIRRORS. 16-page booklet, "A New Chapter in Reflectivity," gives brief history of development of maker's industrial reflecting surfaces; lists advantages, applications.—Pancro Mirrors, Inc., Glendale, Calif.

S-52 CONSTANT TEMPERATURE & HUMIDITY CABINET. 2-page bulletin illustrates and describes maker's "Model 206CD" constant temperature and humidity laboratory cabinet; lists features; discusses construction.—Food Technology Inc., 5903 Northwest Highway, Chicago 31, Ill.

S-53 LEVEL MEASUREMENT. 24-page Catalog 75 illustrates and describes maker's

Graduate Electronic Engineers or Physicists with from 3 to 10 years experience in the following fields. (a) UHF and VHF circuit and antennae design, (b) design of servi-mechanisms and control circuits, (c) design of carrier-type strain gage recording systems. The position will require personnel who can supervise engineers and/or technicians, design equipment and follow construction and necessary trouble-shooting after installation. This work is required for the flight testing of piloted and pilotless aircraft. Write Chance Vought Aircraft, P. O. B. 5907, Dallas, Texas.

"Levelimeter" instruments for indicating, measuring and controlling liquid level and interface level; discusses features, applications.—Fischer & Porter Co., Hatboro, Pa.

S-54 TEMPERATURE INDICATORS. 8-page Bulletin GEC-565 illustrates and describes maker's thermocouple and resistance thermometers and accessories; gives specifications, classification tables, features.—Apparatus Dep't, General Electric Co., Schenectady 5, N. Y.

S-55 "WHAT'S NEW FOR THE LABORATORY?" 12-page No. 9 issue of this house organ contains articles on maker's laboratory apparatus, instruments, chemicals, glassware, etc.—Scientific Glass Apparatus Co., Inc., 49 Ackerman St., Bloomfield, N. J.

S-56 JACKS, PLUGS, SWITCHES. 12-page Catalog No. S49 describes and illustrates maker's phone jacks, plugs, switches; discusses several models of each; gives specifications, drawings. —Switchcraft, Inc., 1328-30 N. Halsted St., Chicago 22, Ill.

S-57 "hp JOURNAL." 4-page Vol. 1, No. 4 issue of this house organ features part two (conclusion) of article titled "Design Notes on the Resistance-Capacity Oscillator Circuit," contains typical characteristics chart of resistance-capacitance oscillators.—Hewlett-Packard Co., 395 Page Mill Rd., Palo Alto, Calif.

S-58 "GENERAL RADIO EXPERIMENTER." 8-page Vol. XXIV, No. 7 issue of this house organ features articles titled "A Precision Attenuator Having a Wide Frequency Range," and "An Acoustic Calibrator for the Sound-level Meter."—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

S-59 "CURRENTLY." 8-page Vol. 3, No. 2 issue of this house organ features article titled "Load Regulation" discussing use of voltage regulators, linear and non-linear loads.—Sorensen and Co., Inc., 375 Fairfield Ave., Stamford, Conn.

S-60 TRANSFORMERS. 18-page Catalog 1950-I describes and illustrates maker's output, input, interstage, plate and filament, power smoothing and swinging chokes, modulation and replacement type transformers; lists characteristics.—Peerless Electrical Products Div., Altec Lansing Corp., 161 Sixth Ave., New York 13, N. Y.

S-61 "WHEELCO COMMENTS." 4-page Vol. 9, No. 1 issue of this house organ features

A supply of these cards for the asking

Is your copy of *Instruments* routed to several people?

Does your Company Librarian forbid mutilating tech mags?

Or do you yourself wish to preserve your own copies intact?

Just drop us a postal card asking for Inquiry Cards and we'll send you twelve! Do it NOW.

Just Published!

Operation and Care of Circular-scale Instruments

By JAMES SPENCER, for twenty years in charge of Instrument and Relay Department, Meter Division Westinghouse Electric Corporation

CONTENTS

EDITOR'S FOREWORD

AUTHOR'S PREFACE

CHAPTER I—ESSENTIAL TOOLS

CHAPTER II—D-C. INSTRUMENTS

Dismounting and Reassembling, 5—KX-124 Instruments, 5—DB-12 Instruments, 11—Test and Inspection, 12—Principles of Operation, 19—Maintenance, 20—Connections, 22.

TROUBLE CHART FOR D-C. INSTRUMENTS

CHAPTER III—A-C. AMMETERS AND VOLTMETERS

Principles of Operation, 24—Construction, 25—Dismantling KA-24 Instrument, 28—Reassembling, 33—Dismantling DB-12 Instrument, 34—Test and Inspection, 35—Internal and External Connections, 36—Maintenance, 36.

CHAPTER IV—ELECTRODYNAMIC TYPE INSTRUMENTS

WATTMETERS, 39—Construction, 39—The KF-24 Wattmeter, 39—The AB-12 Wattmeters, 48—Connections, 49—Principle of Operating, 49—Inspection and Calibration, 51—Single-phase Wattmeter, 52—Poly-phase Wattmeter, 53—Maintenance, 53.

FREQUENCY METERS, 56—Construction, 56—The KF-24 Instrument, 56—The AB-12 Instrument, 60—Principles of Operation, 61—Test and Inspection, 63—Maintenance, 66.

CHAPTER V—POWER FACTOR METERS AND SYNCHROSCOPES

POWER FACTOR METERS, 67—General Description, 67—Dismounting and Reassembling, 69—Inspection and Calibration, 74—Maintenance, 77.

SYNCHROSCOPES, 81—Description, 81—Inspection and Test, 83—Maintenance, 85.

TROUBLE CHART FOR A-C. INSTRUMENTS

Cloth, 5 x 8 inches, 90 pages. Profusely illustrated with circuit diagrams, schematic diagrams, and photographs.

$1.50 POSTPAID

Payment must accompany order

THE INSTRUMENTS PUBLISHING COMPANY, INC.

921 Ridge Avenue, Pittsburgh 12, Penna.

Here is your LITERATURE and INFORMATION order card

Instruments, 921 Ridge Ave., Pittsburgh, Pa. *(January 1950)*

Please have the following catalogs, etc., reviewed in this issue sent to me.

Numbers

I desire further information on devices described in the "New Instruments" Dep't:

Numbers

I also desire further information concerning the following products advertised in this issue (Write page number and name of company)

☐ *Check if you wish a Group Subscription Plan Form sent to you.*

Name

Company Position

Co.'s Address

(OR) Home Address